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ORIGINAL ARTICLES.

I.—Note on the Pelvis of *Cryptoclidus Oxoniensis* (Phillips).

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Among the Plesiosaurian remains recently mounted for exhibition in the Reptile Gallery at the Natural History Museum is a very fine pelvic-girdle belonging to a species of the genus *Cryptoclidus* (Seeley), and forming part of the same skeleton (Leeds Coll., R. 2616) as the pectoral-girdle recently described and figured by the present writer.[1] These specimens are perhaps the most perfect known, the bones being quite uncrushed, free from matrix, and, except that they are cracked and broken to a slight degree, in much the same condition as if they had been obtained by maceration from a recent reptile. They clearly belonged to an old individual in which ossification had nearly reached its maximum: this is shown (1) by the complete union of the coracoid and scapula with one another in the middle line closing the coraco-scapular foramen; (2) by the sharpness of some of the edges of the bones, *e.g.* of part of the anterior border of the pubis; (3) by the great solidity of the bones, and by the accuracy with which the pectoral and pelvic elements fit together to form the glenoid and acetabular cavities respectively, showing that the cartilage which separates them in the young animal had been ossified.

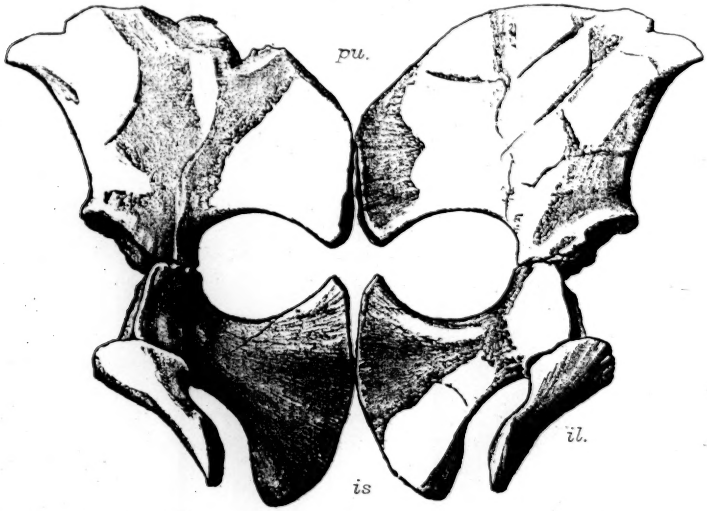
A mounted pelvis of *Murænosaurus* has been already described and figured,[2] and if the present specimen be compared with it, it will be seen that the differences between the two genera in this part of the skeleton are considerable. Some of the more important of these differences are pointed out below.

Pubis.—The pubis is proportionately much wider from side to side and shorter from before backwards than that of *Murænosaurus*. Its anterior convex border is thin, except near the outer angle, where it is thickened and produced into a short stout process, which is

[1] "On the Development of the Shoulder-girdle of a Plesiosaur (*Cryptoclidus Oxoniensis*, Phillips, sp.) from the Oxford Clay": Ann. Mag. Nat. Hist., ser. 6, vol. xv (1895), pp. 335–40, figs. 1 and 2.

[2] "On the Pectoral and Pelvic Girdles of *Murænosaurus plicatus*": Ann. Mag. Nat. Hist., ser. 6, vol. xvi (1895), pp. 432–4, figs. 2 and 3.

separated from the inner portion by a notch. This process is also present in *Muræosaurus*, in which, however, it is much less prominent and does not stand out beyond the level of the acetabulum to nearly the same extent; it appears to be homologous with the lateral pubic process (ectopubis of Baur) of the chelonian pubis.



Pelvis of *Cryptoclidus oxoniensis* (Phillips) from above, from the Oxford Clay, Fletton, near Peterborough. *pu.* pubis; *is.* ischium; *il.* ilium. One-seventh natural size.

The symphysial surface is much shorter than in *Muræosaurus*, but at the same time much deeper. It is spindle-shaped, about 16 cm. long and 6 deep, the bone being very thick at this point. The curvature of the symphysial border shows that the two pubes were only in actual contact (if at all) at one point, in front of and behind which they were separated by wedges of cartilage. The anterior cartilage (epipubic) was probably small and continuous with that fringing the anterior border; while the posterior was thick and no doubt continuous with that between the anterior ends of the ischia, which were separated from the pubes by an interval of about 2 cm. This median bar of cartilage, which divided the *foramina obturatoria* and most likely persisted even in the oldest individuals, corresponds with the similarly situated cartilage (mesogastroid of Baur) in many chelonian pelves.

The concave posterior border thickens gradually from within outwards to the ischial surface. This latter is nearly semicircular, the diameter of the semicircle forming the line of division between it and the acetabular surface, the length of which from before backwards is about 8 cm.

Ischium.—The ischium is of the usual hatchet shape. The anterior portion of its median border is thick and bears a spindle-shaped surface for the cartilage of the symphysis; behind this the bone

thins suddenly, thickening again towards the posterior angle. The two ischia were separated in front by cartilage which, as already mentioned, was probably continuous with that between the pubes; posteriorly there was, no doubt, a small "hypogastroid" cartilage.

The articular end of the ischium is extremely massive, measuring about 7 cm. in thickness at the acetabulum. As in *Muræosaurus*, it bears three articular surfaces: of these, the anterior, for the pubis, is nearly semicircular; the median, forming the middle part of the acetabulum, is roughly rectangular, and measures 6 cm. from before backwards; the posterior, for the ilium, is about 5 cm. long, and looks backwards and only slightly upwards, the ilia being directed much more backwards than in *Muræosaurus*.

The dimensions of the ischium are—

	cm.
Width from acetabulum to middle of symphysial surface	22
Length between the anterior and posterior inner angles	21
Width of neck at narrowest point	6·8
Circumference ,, ,, ,, ...	16

Ilium.—The ilium is a very stout, slightly curved rod of bone. Its lower end is greatly thickened, and is truncated by an oblique oval surface, the long diameter of which is 7·5 cm. in length; the short, 4·5 cm. The inner two-thirds of this nearly flat surface articulate with the iliac surface of the ischium, while the outer third forms the posterior wall of the acetabulum. The outer angle of the acetabular region is occupied by a small surface for cartilage, which probably capped this portion of the bone and was continuous with that lining the acetabulum. The middle of the ilium is contracted and is slightly oval in section. The upper portion is compressed and somewhat like the blade of an oar. The anterior border of this expanded region is thin and sharp, the posterior thick and rounded; its upper edge is curved and bears a surface for cartilage. The inner face of the upper portion of the ilium is flat and shows scarcely any trace of its union with the sacral ribs, to which it was probably only loosely attached by ligaments. The distance between the upper ends of the ilia is about 23 cm. The length of the ilium is 20 cm., the width of its upper end 6 cm., and the circumference of the shaft at the narrowest point about 11 cm. The lower end of the left ilium has been restored in plaster.

Looking at the pelvis as a whole, it will be seen that it presents some peculiar characters. The pubes and ischia of the opposite sides do not make a distinct angle with one another; on the contrary, their middle portions are almost in the same plane, and the visceral surface of the pelvis is only gently concave from side to side. This, combined with its great width, gives the whole pelvis a peculiar appearance of extreme shallowness and expansion. From before backwards the visceral surface is strongly convex, its highest point between the acetabula being only about 8·5 cm. below a straight line joining the middle points of the upper borders of those cavities. In front of and behind this point it slopes away towards the anterior and posterior borders of the pelvis.

Another point worthy of notice is the extreme backward slope of the ilia. This is so great, that if, when the ischia and pubes are resting on a plane surface, a line be drawn along the long axis of the ilium, it makes an angle of little more than 30° with that surface. In many lizards and chelonians the ilia are directed backwards to a considerable extent, but in none, as far as I am aware, to such a degree as this. It seems not improbable that in the living animal the ventral surface of the pelvis sloped downwards and forwards, so that the position of the ilia would be less oblique to the vertebral axis than might be supposed.

The causes of the peculiar structure of the acetabulum and of the great backward slope of the ilium must, no doubt, be sought in the mechanical conditions under which the animal existed, and although these conditions are too little known and too complex to permit of a complete solution of the problem, the following tentative explanation may be offered. It is generally admitted that the Plesiosaurs are descended from land reptiles, in which, of course, one of the chief functions of the skeleton would be to support the soft parts, and in the case of the pectoral and pelvic girdles to transmit the weight of the body to the supporting limbs: in this case the thrust on the heads of the humerus and femur is mainly a vertical one. When such an animal becomes wholly aquatic in its habits these conditions are completely changed. In the first place, the body is supported on all sides by the pressure of the water; in the second, the limbs no longer bear up the body weight, and if, as in the Plesiosaurs, they are used as paddles, there would be a nearly horizontal (forward) thrust of the heads of the humerus and femur at each stroke. In the case of the pelvic-girdle of the Plesiosaurs the result is exactly what, *a priori*, we should expect from such change of conditions. The upper end of the ilium is a fixed point (to the sacral vertebræ), about which the forward thrust of the femur would tend to produce rotation leading to the backward slope we have seen actually exists. In the next place, the same force would produce the elongation from before backwards of the acetabulum; and this elongation, together with the backward rotation of the ilium, seems to have led to the separation of the latter bone from the pubis, and the result is an elongated acetabulum constituted by the articular surfaces of the pubis, ischium, and ilium, arranged in a linear series from before backwards. As to the means by which this has been brought about, opinions will differ, but in any case it seems at least highly probable that the change in the conditions of life has resulted in the peculiarities above described. In this connection it is interesting to notice that among the Chelonia, certain of which show greater similarity to the Plesiosaurs in their pelvic-girdles than any other reptiles, the marine forms, such as *Chelone*, have backwardly directed ilia, while the exclusively terrestrial ones, such as *Testudo pardalis*, have those bones nearly vertical; in the fresh-water tortoises both types occur.

II.—The Mineral Springs of the Baden District (Switzerland).

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.C.S.

As is well known, there are in Switzerland a good many cold mineral, but very few powerful thermal springs,[1] a fact which is in a great measure due to the scarcity of the younger series of eruptive rocks, such as give rise to the abundant hot springs of Bohemia, the Taunus and Eiffel districts, Auvergne, the Pyrenees, and other localities possessing similar geological features.

The only really powerful and abundant thermal, but non-volcanic, springs in Switzerland are those of Pfävers (Ragatz) in the Rhine valley, of Louèche in the Rhone valley, and of Baden in the Limmat valley. At Pfävers, as at Louèche, the springs are confined to one locality, whilst the Baden district comprises, besides the springs of Baden proper, a whole cluster of different mineral springs, spread over an area of about ten square miles. It is this area which the writer has lately had an opportunity of examining.

At first sight, it seems remarkable that so great a number and variety of mineral springs should be met with in the Molasse formation, which, broadly speaking, constitutes the Subalpine hills east of the river Aare; but on closer examination, it is found that all those springs are situated along the same zone—to wit, at the base of an isolated Jurassic ridge which lies between the Jura range and the Central Alps, and, like these two mountain chains, was raised and folded in Miocene times. The Jurassic outcrop extends for about sixteen miles from the left bank of the river Aare, near Aarau, to about seven miles beyond Baden, its strike being south-west to north-east, that is, in the main parallel to the strike of the Jura and the Central Alps.

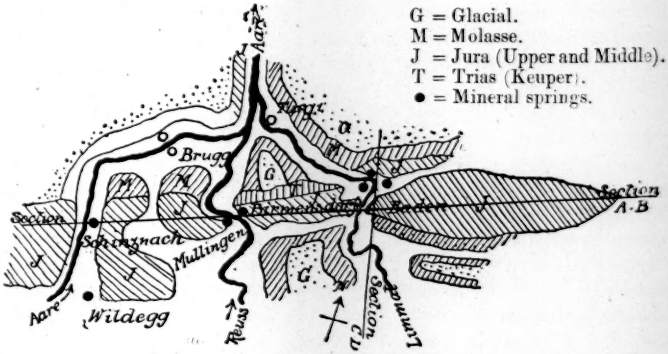


Fig. 1.—Plan of the Baden District. $\frac{1}{250000}$.

As is seen from the plan and longitudinal section (Figs. 1 and 2), the Jurassic ridge rises at both ends to the considerable elevation of

[1] Among the cold mineral springs, the most notable and abundant are those of St. Moritz and Tarasp, in the Engadine, and of Rheinfelden, near Bâle.

730 and 860 metres (2,400 and 2,830 ft.) above sea-level, and at its north-west end, near and beyond Baden, constitutes the so-called "Laegern" ridge, whose altitude exceeds that of the surrounding Molasse hills by fully 800 feet. In its central portion, the ridge is intersected at right angles by the rivers Limmat, Reuss, and Aare, at a distance of about four miles from their confluence near Turgi.

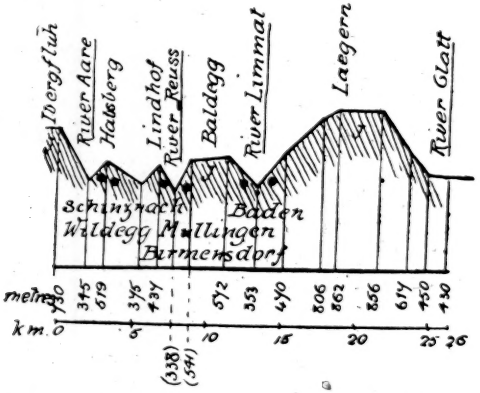


FIG. 2.—Longitudinal section. Schinznach–Birmensdorf–Baden. Horizontal $\frac{1}{50000}$; vertical $\frac{1}{10000}$.

It is at the point of intersection of those rivers that the mineral springs of Baden (Limmat valley), of Birmensdorf and Mullingen (Reuss valley), and of Schinznach and Wildegg (Aare valley) rise to the surface, their position coinciding in the main with the anticlinal axis of the Jurassic fold, as is shown in the plan and longitudinal section.

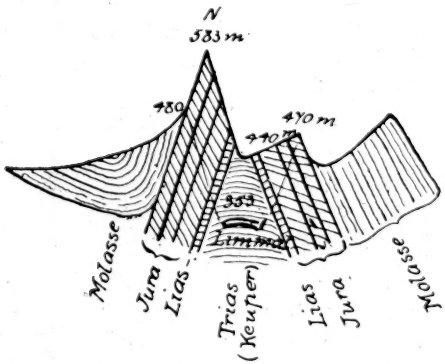


FIG. 3.—Transverse section. Baden. Horizontal $\frac{1}{10000}$; vertical $\frac{1}{10000}$.

A typical transverse section of the ridge is the one exposed at Baden (Ennetbaden), on the right bank of the river. It is represented in Fig. 3, and is about 1·6 kilometre, or one mile, in length, the outer strata on each side of the fold being composed of Upper or

white Jura (Malm) and of Middle or brown Jura (Dogger), the intermediate strata of Lias, and the central or lowest strata of Keuper (Trias), which last-named therefore lies in the axis of the anticlinal fold. The more or less uniform character of this section throughout the ridge is attested by the fact that the various mineral springs rise from along the line of junction of the Keuper and the younger strata.

The distinctive features of the four varieties of mineral springs in the district, and of their occurrence, may be briefly stated as follows:—

1. *Baden Springs*, 360 metres (1180 ft.) above sea-level.[1] As is seen from the plan, Fig. 4, all the Baden springs rise in a sharp

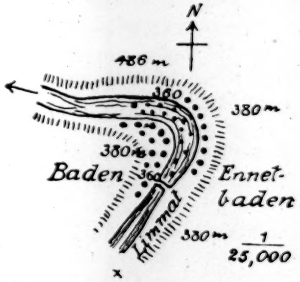


FIG. 4.—Mineral springs of Baden, Switzerland.

curve of 60 degrees formed by the Limmat at a point where the river has eroded the glacial gravels of the valley to a depth of about 20 metres, or 66 ft., down to the Keuper, which at this point crosses the bed of the river. The springs issue through fissures between the Keuper and the Jurassic strata which, as already shown in the transverse section, cross the valley in two separate ridges, forming the Baden basin. On the left bank of the river, the Keuper is overlain by about 30 ft. of clay and marl, which, somewhat further down the river, are overlain by sand and glacial Nagelfluh to a depth of about 66 ft. On the right bank, the same clay and marl, alternating with gypsum bands, are about 50 ft. in depth, and overlie a compact dolomite.

The springs on both sides of the river number twenty-one, while about fifteen more issue in the river-bed and are lost. The principal mineral constituents of the water are, in 1,000 parts: sulphate of sodium, 1·842; chloride of calcium, 1·3; chloride of sodium, 0·3; bicarbonate of magnesium, 0·3; and some free sulphuretted hydrogen. As is seen, these constituents are the products of the decomposition and reaction upon each other of the principal compounds composing the rocks characteristic of the Middle Keuper formation—to wit, gypsum (sulphate of calcium), common salt (chloride of sodium), and dolomite (carbonate of magnesium).

[1] These springs have been known for nearly 2,000 years, Baden having been, like Windisch (Vindonissa), near Turgi, four miles below Baden, occupied by the Romans as early as 61 B.C.

The springs have a temperature of 46° C. (115° F.), and are not affected by the rise or fall of the river Limmat, but vary according to the rainfall at different seasons, a fact which shows that they are derived from atmospheric water percolating through the various strata. The fact that the chemical composition of all the twenty-one springs is fairly uniform, warrants the conclusion that they all rise from one source or collecting-basin. Assuming the temperature of the atmospheric water at the surface to be 10° C., and the increase of temperature to be 1° C. every 30 metres, the temperature of the Baden springs corresponds to a depth of the subterranean reservoir of $(46-10)\times 30=1{,}080$ m., or about 3,500 ft. The probable seat of the reservoir is therefore not below the Keuper or upper member of the Trias. The average yield of the springs is in the aggregate no less than 1,000,000 litres (222,000 gallons) in 24 hours. Both in yield and temperature, the Baden springs vie with other celebrated thermal springs, such as those of Pfävers and Aix-les-Bains, which have a temperature of 36° C. (97° F.) and 45° C. (113° F.) respectively.

2. *Birmensdorf and Mullingen*, 340 metres (1,115 ft.) above sea-level. These are cold springs, containing chiefly sulphate of magnesium, sulphate of sodium, and sulphate of calcium, from the dolomitic and gypsum strata. In addition to the natural springs, mineral water is produced by leaching the strata in tanks formed in pits at a depth of 100 metres (330 ft.) below the surface. The springs and tanks are capable of yielding about 1,000,000 litres (220,000 gallons) per annum, but the abundance of gypsum dykes, which have already been worked for more than 70 years, is such that the production can be largely increased.

The Birmensdorf water has a temperature of 15° C. (59° F.), and a specific gravity of 1·17. In mineral composition it compares as follows with the well-known similar waters of Friedrichshall and Hunyadi Janos :—

	In 1,000 parts.			
	Sulphate of Magnesium.	Sulphate of Sodium.	Sulphate of Calcium.	Chloride of Sodium.
Friedrichshall	5·15	6·05	1·34	7·96
Birmensdorf	12·04	16·56	—	1·30
Hunyadi Janos.....	24·35	22·55	0·32	—

The mineral water of Mullingen is very similar to that of Birmensdorf, being derived from the same Triassic and Jurassic strata which are intersected by the river Reuss.

3. *Schinznach*, 343 metres (1,125 ft.) above sea-level. This is an abundant thermal spring, somewhat similar to the springs of Baden, and rises from the dolomitic and gypsum strata about 30 ft. below the surface. It contains, in 1,000 parts : carbonate of calcium, 0·25; carbonate of magnesium, 0·12 ; sulphate of calcium, 1·10 ; and some free sulphuretted hydrogen. The spring has a temperature of 35° C.

(95° F.), and yields about 720,000 litres (160,000 gallons) in 24 hours, which quantity is, however, easily capable of being trebled.

The Schinznach spring bears analogy more especially to the springs of Louèche (1,415 m. or 4,641 ft. above sea-level), which contain, in 1,000 parts, 1·48 sulphate of calcium and 0·23 sulphate of magnesium, but have a higher temperature, viz. 45° C. (113° F.), while their considerably larger aggregate yield amounts to 6,000,000 litres (1,312,000 gallons) in 24 hours.

4. *Wildegg*, 356 metres (1,168 ft.) above sea-level. This is a saline spring, rising at the bottom of an artesian well at a depth of 256 m. (about 840 ft.) below the level of the river Aare. In addition to chloride of sodium, it contains, as characteristic constituents, iodine and bromine. The temperature of the spring is 15° C. (59° F.), and its present yield is only about 75,000 litres (17,000 gallons) per annum.

Appendix.

In the following Table the writer has determined by calculation the probable depths below the surface of upwards of 30 well-known or otherwise remarkable thermal springs, with the great majority of which he is acquainted, and whose temperatures, according to official statistics or otherwise authentic records, range from 20° to 90° C., or 68° to 194° F. The formula used is that already given for determining the depth of the Baden springs—

$$(\text{Temperature of spring} - 10° \text{ C.}) \times 30 = \text{depth in metres.}$$

If no allowance be made for the initial temperature of the atmospheric water percolating through the rocks down to the collecting-basin—in other terms, if the temperature at the surface be taken at 0° C. (32° F.), the depths given in the Table have to be increased by 300 metres, or 1,000 ft.

Depth of Thermal Springs

having Surface-Temperatures of 20° to 90° C. (68° to 194° F.).

No.	Name of Spring.	Country.	Temperature at surface.		Depth below surface.	
			Cent.	Fahr.	Metres.	Feet.
1	Matlock	England	20°	68°	300	984
2	Munster (Crenznach)	Germany	23	73	390	1279
3	Buxton	England	28	82	540	1771
4	Montecatini	Italy	30	86	600	1970
5	Royat	France	35	95	750	2461
6	Schinznach	Switzerland	35	95	750	2461
7	Pfäfers (Ragatz)	Switzerland	36	97	780	2558
8	Baden (Vienna)	Austria	36	97	780	2558
9	Poretta	Italy	36	97	780	2558
10	Wildbad	Germany	37	98	810	2657
11	St. Gervais	France	38	100	840	2755
12	Neuenahr	Germany	39	102	870	2854
13	Nauheim	Germany	39	102	870	2854
14	Teplitz	Austria	40	104	900	2953
15	Vichy	France	43	109	990	3248
16	Aix-les-Bains	France	45	113	1050	3444
17	Louèche	Switzerland	45	113	1050	3444
18	Baden	Switzerland	46	115	1080	3542

No.	Name of Spring.	Country.	Temperature at surface.		Depth below surface.	
			Cent.	Fahr.	Metres.	Feet.
19	Ems	Germany	48°	118°	1140	3739
20	Bath	England	49	120	1170	3838
21	Luchon	France	50	122	1200	3936
22	Bormio	Italy	50	122	1200	3936
23	Plombières	France	52	126	1260	4133
24	Aix-la-Chapelle	Germany	55	131	1350	4428
25	Warazia	Austria	56	133	1380	4526
26	Carlsbad (Sprudel)	Austria	60	140	1500	4920
27	Aqui	Italy	64	147	1620	5314
28	Wiesbaden	Germany	68	155	1740	5708
29	Baden-Baden	Germany	68	155	1740	5708
30	Gastein	Austria	70	158	1800	5906
31	Ischia (Gurgitello)	Italy	70	158	1800	5906
32	Chaudes-Aigues (Par)	France	87	188	2310	7577
33	Peters-Spring (Caucasus)	Russia	90	194	2400	7872
34	Las Trincheras	Venezuela	90	194	2400	7872
Intermittent Springs.	Geysers of Iceland	Iceland	100 mean temp.	212	2700	8856
	,, New Zealand	New Zealand				
	,, Yellowstone Park	U.S.A.				

It is seen that out of the 34 permanent thermal springs enumerated in the Table, 19, or more than half, have temperatures ranging from 30° to 50° C. (86° to 122° F.), and corresponding to a depth of 600 to 1,200 metres, or about 2,000 to 4,000 feet below the surface, while the average temperature of the Geysers, viz. boiling-point, corresponds to a depth of 2,700 metres, or about 9,000 feet. Great as these depths appear, even the maximum is less than one-third of the aggregate thickness (commonly computed at about 30,000 feet) of the successive formations composing the earth's crust down to the Archæan rocks, and only 0·04 per cent. or $\frac{1}{2\,3\,7\,0}$th of the radius of the globe (about 4,000 miles).

III.—On the Sandstones in the Upper Keuper in Warwickshire.

By the Rev. P. B. Brodie, M.A., F.G.S.

I HAVE read with much interest Mr. Horace Brown's account in the Geological Magazine for February, 1896, of the boring for water in the Trias at Stratford-on-Avon. In it he makes brief allusion to the sandstones in the Upper Keuper, and refers to Mr. Howell's statement of the occurrence of certain sandstones near Henley-in-Arden. He does not seem to be aware that similar sandstones are more or less widely spread over a considerable area in some parts of the Midlands, north and north-east of Henley and north-west of Warwick at a higher level, the highest point being 445 feet above the level of the sea. Many years ago I noticed some sandstone in Miss Phillips' park at Edstone not given in the Survey Map, and I informed my friend the late Professor Ramsay of the fact. These sandstones may also be seen in many places,

especially in the parish of Rowington. They are exposed on the banks of the canal and along the road leading to Warwick, and were formerly obtained from quarries in the parish now long ago filled up, according to certain old documents in our parish chest, which gives an account of payments made for stone from this place, and our fine church and others in the neighbourhood and some old houses are built of it. When the Great Western Railway was made here a deep cutting through the sandstones was exposed along the line at Finwood in this parish; and lately they were detected when the new line to Henley was constructed. All the higher ridges in this district—they can hardly be called hills—are composed of the sandstones, the lower ground, where the marls and sandstones have been denuded, being formed of the red marls below. Sections are generally rare, as the stone is seldom employed except at Shrewley quarry near here, where the best section of the Upper Keuper beds are exposed. There are about two beds of useful stone: the upper one is inferior to the lower or bottom rock, which is a hard sandstone of some thickness and makes a good building stone, and is used by the Canal Company. This quarry is famous for many interesting fossils so scarce in the Trias, and is noted for the remains of fish, viz., *Semionotus*, *Acrodus* (spines and teeth), footprints of *Labyrinthodon*, and, the rarest of all, moulds of several species of mollusks, the only British locality where any shells have been found. I may add that the wells in the parish are fairly supplied with water from the sandstones, but it is hard and more or less charged with sulphates.

Note.—All the type and unique specimens lately in my collection from the Warwickshire Trias, especially Shrewley and Coten End, are now in the British Museum (Natural History), South Kensington.

IV.—On the Old Red Sandstone and Carboniferous Rocks of the North-east of the Island of Arran.[1]

By James Neilson,
Vice-President of the Glasgow Geological Society.

In the third edition of his Text-Book of Geology, Sir Archibald Geikie has discussed the question whether fossils can be wholly depended upon to indicate the age of rocks when similar or representative species are found in areas wide apart. Thus he tells us (p. 665) that in Bohemia and Russia some of the most characteristic Upper Silurian organisms are found beneath strata replete with Lower Silurian life. Again, speaking of the close of the Silurian period, he says (p. 760): "There is every reason to believe that for a long time the marine sedimentation of Upper Silurian type continued to prevail in some areas, while the probably lacustrine type of the Old Red Sandstone had already been established in others." He also tells us (p. 828) that "In the West of Scotland there occur among the red sandstones (some of which contain Old Red Sandstone fishes) bands

[1] Read before the Glasgow Geological Society on 17th October, 1895.

of limestone full of true Carboniferous Limestone corals and brachiopods." Again (p. 665), he draws our attention to the statement that "In Australia a flora with Jurassic affinities and a Carboniferous Limestone fauna were contemporaneous"; while we may conclude our extracts by one which says: "At the present day the higher fauna of Australia is more nearly akin to that which flourished in Europe far back in Mesozoic time, than to the living fauna of any other region of the globe."

The above quotations and extracts show the way in which palæontological evidence may be treated by those who strictly follow Prof. Huxley's views on homotaxis; and without offering any opinion on other matters, I propose to proceed to the consideration of that part which concerns the West of Scotland, viz., the question whether marine Carboniferous Limestone fossils are found in Old Red Sandstone strata.

Again, I quote (p. 801) from the chapter on Old Red Sandstone:—"In the Upper Old Red Sandstone of the Firth of Clyde *Bothriolepis* (*Pterichthys*) *major* and *Holoptychius* occur at the Heads of Ayr; while a band of marine limestone, lying in the red sandstone series of Arran, is crowded with ordinary Carboniferous Limestone shells, such as *Productus giganteus, P. semireticulatus, P. punctatus, Chonetes hardrensis, Spirifer lineatus*, etc. These fossils are absent from the great series of red sandstones overlying the limestone, and do not reappear till we reach the limestones in the Lower Carboniferous series; yet the organisms must have been living during all that long interval outside of the Upper Old Red Sandstone area. Not only so, but they must have been in existence long before the formation of the thick Arran limestone, though it was only during the comparatively brief interval represented by the limestone that geographical changes permitted them to enter the Old Red Sandstone basin and settle a while on its floor. The higher parts of the Upper Old Red Sandstone seem thus to have been contemporaneous with a Carboniferous Limestone fauna, which, having appeared beyond the British area, was ready to spread over it as soon as the conditions became favourable for the invasion. It is, of course, obvious that such an abundant and varied fauna as that of the Carboniferous Limestone cannot have come suddenly into existence at the period marked by the base of the limestone. It must have had a long previous existence outside the area of the deposit."

Sir Archibald Geikie also returns to the subject when treating of the Carboniferous system, thus (p. 828): "Hence it is evident that the Carboniferous Limestone fauna had already appeared outside the British area before the final cessation of the peculiar conditions of sedimentation of the Old Red Sandstone period."

The fact is, that no Old Red Sandstone fishes have been recorded, and, so far as we are aware, none have ever been found in Arran. The fishes referred to by Geikie were, I presume, those from the Red Sandstone south of the Heads of Ayr, on the mainland of Scotland, some twenty miles distant from the Arran limestone.

Arran is classic ground to the geologist, and its fame has travelled

far beyond the limits of the United Kingdom and has engaged many pens. In particular, Sedgwick and Murchison,[1] A. C. Ramsay,[2] Dr. James Bryce,[3] and others, have written of these particular rocks, and all recognized, not only Old Red Sandstone, but also Carboniferous rocks, and their writings on the subject are full of most interesting facts, with carefully reasoned deductions.

The northern half of the Island of Arran consists, first, of a central granite nucleus of somewhat circular form, which embraces all the higher hills. This granite nowhere reaches the sea, being surrounded by a complete ring of slate and schistose rocks. These are overlain by another series of rocks, among which red is the prevailing colour; but the latter only form three-fourths of a circle. Previous writers on Arran had assigned these latter rocks partly to the Old Red Sandstone and partly to the Carboniferous formations, and it is to them that we wish to direct attention, with the view of going over the evidence already recorded, and also of adding any observations we ourselves have been able to make. Observation here is very much facilitated by the fact that the intrusion of the granites (or final intrusion, if there were more than one) occurred subsequent to the deposition of the highest of the sedimentary rocks, which are elevated all round the coast, and their edges being exposed by the tides afford unrivalled opportunities for geological investigation.

As was first pointed out by Sedgwick and Murchison, the lowest of these Old Red Sandstone rocks on the beach are seen at North Sannox, where there is an anticline from which the rocks dip respectively to the north and south. They consist mostly of red sandstones and conglomerates, and, as will readily be acknowledged, the rocks north of the anticline correspond with those to the south. Sedgwick and Murchison set down these rocks as Old Red Sandstone, which, according to them, extended for about three miles along the shore, the northern junction with the Carboniferous occurring to the north of the fallen rocks, and the southern a quarter of a mile north of Corrie.[4] These rocks are then overlain by Carboniferous rocks for several miles both north and south, and are finally overlain by rocks of the New Red Sandstone age. Ramsay also supports this theory, and Bryce only differs from it in referring the uppermost rocks to the Upper Carboniferous instead of the New Red Sandstone. The writer's own observation has led him to the conclusion that these writers were mainly correct, and, although aware of Sir A. Geikie's views, he yet did not feel justified in questioning them till he had an opportunity of again traversing the ground.

[1] Proceedings of Geological Society of London, vol. i, p. 41 (1828). This appears to be only an abstract of their paper.

[2] "Geology of the Island of Arran," by (Sir) Andrew Crombie Ramsay, 1841.

[3] "Geology of Arran and other Clyde Islands," by James Bryce, M.A., LL.D., 4th edition, 1872.

[4] That is, 100 yards north of the great split boulder which forms such a conspicuous object on the shore.

No time need be lost in discussing the beds described by Sedgwick and Murchison as Old Red Sandstone—that point is admitted on all hands; the question is, whether the beds considered by them and subsequent writers to be Carboniferous, are really so, or Old Red Sandstone as Sir A. Geikie contends. For this purpose we come to the junctions of these formations, and find that both on the north and south the Old Red Sandstone conglomerates are succeeded by calcareous conglomerates and limestones (cornstones), alternating with sandstones. These strata overlie the Old Red Sandstone conglomerates conformably, and if Arran alone had been in question it is doubtful whether the line would have been drawn here. Unfortunately the strata at the south end are cut off about 40 yards from this junction by a dike whose cross section extends over 320 yards along the shore, and as it seems to us that this dike marks a fault cutting off a considerable thickness of strata we are compelled to fill in the gap by reference to the corresponding northern section, where we find this same cornstone series overlain by beds of sandstone, black shale, and volcanic ash. This shale contains charred plant-remains belonging to *Calamites*, *Lepidodendron*, *Lepidostrobus*, also a species of *Spirorbis*, besides, what is even of more interest, it contains the remains of fishes. These have been submitted to Dr. Traquair, whose report is to the effect that, while the specimens were too fragmentary to identify specifically, still one basal part of a tooth probably belonged to the genus *Rhizodus*; another tooth resembled *Strepsodus striolatus*, Traq. There are also an imperfect Rhizodont scale, and some scales probably belonging to *Rhadinichthys*, Traq. He concludes his report as follows: "Although the specimens are, unfortunately, not such as to permit me to give any list of species, it is to be noted that they exhibit an unmistakably Carboniferous facies."

Overlying this shale is a bed of volcanic ash, also containing *fish*-remains, consisting of fragments of bones and scales—some pretty large, but I was not fortunate in finding anything in a condition to admit of being named. The information with regard to this latter bed was obtained from Mr. James Thomson, F.G.S., whom I believe to be the discoverer, and it was in searching for it that I stumbled across the black shale above mentioned. It speaks volumes for the accuracy of the old writers that here, within a few yards of the line they drew as separating the Old Red and Carboniferous formations, should be found a bed charged with characteristic Carboniferous fossils. This is also the lowest horizon, so far as I am aware, where Carboniferous fossils have been found, and, as will afterwards be shown, it occupies a position several hundred fathoms below the marine limestones which were formerly grouped with the Old Red Sandstone formation.

Proceeding onwards, it should be remembered that owing to the anticline the rocks dip away from the observer in the direction in which he is travelling, so that he sees first only the upturned edge of the rock. It will thus be evident that each bed met with is higher

in the section than the preceding bed, and as the strata dip at angles of from 20° to 70°, a mile along the shore represents a considerable thickness of strata. From this point onwards for a distance of about three miles the red colour of the rocks is very exceptional indeed, and not until one passes the Salt Pans does he come again to the predominating red rock, and then, as will afterwards be shown, at a horizon several thousand feet higher up in the geological scale.

Succeeding and overlying the fish-beds is a great thickness of white calciferous sandstones, till at Millstone Point, about one mile north of the fallen rocks, black shales are met with full of plant-remains in the condition of anthracite. The observer next reaches the sections of trap and ash beds, interbedded with shales and thin seams of coal, among which the late Mr. E. A. Wünsch made his interesting discovery of a forest entombed in volcanic ash, yet in such a way as to preserve the minute structure of the plants.[1] Mr. Wünsch recorded the disinterment of fourteen large tree stems, and some more were dug out during the meeting of the British Association in Glasgow in September 1876.

Dr. Bryce (p. 127) also records the finding of a palatal tooth of *Ctenodus cristatus*—surely a Carboniferous fish. The plants recorded from this bed are: ***Sigillaria***, ***Halonia***, ***Lepidodendron***, ***Lepidostrobus*** (3 species), ***Antholithes***, ***Sphenopteris***, ***Stigmaria***, and ***Strobilites***. Mr. Wünsch estimated the thickness of the igneous rocks, with interbedded shales, etc., at about 1000 feet, and between these and the Old Red Conglomerate there will be, I should think, at least as much more.

The limestones (which are reached after passing some white or grey sandstones) follow next in succession, so that there are here some 2000 feet of strata underlying the fossiliferous limestone. I do not hesitate to assign these strata to the Calciferous Sandstone series, and the great thickness of the igneous rocks among which Mr. Wünsch's discovery was made, to the great outburst of Trap which extends over Scotland, and has given origin to the Trap hills of South Bute, Little Cumbrae, North Ayrshire, Kilpatrick, Campsie, Fifeshire, and the Lothians.

The fossiliferous limestone which occurs about 100 yards north-west of the shepherd's house at Laggan is undoubtedly the same as that at Corrie, and contains the same fossils, the prevailing one being *Productus giganteus*, which is extraordinarily abundant. The peculiarity about these is that the shales are black, while at Corrie they are red, thus showing that the red colour is merely a local phenomenon, even in Arran.

These limestones are succeeded by white and grey sandstones and black shales alternating. Some of the shales are charged with the usual marine Carboniferous fossils, and extend along the shore to Salt Pans, where they are succeeded by beds of a different character;

[1] Trans. Geol. Soc. Glasgow, vol. ii, p. 97. For descriptions of new species from this deposit, see Mon. Palæont. Soc. 1870; Geol. Mag. 1865, p. 474; *ibid.* 1867, p. 551.

but, as these beds are not represented on the southern part of the district, I propose to defer their consideration till I take up the others.

To return now to the consideration of the similar beds at the southern portion of the section, viz. at the 320 yards broad dike, whose southern edge terminates on the shore, opposite the school grounds at Corrie. As already stated, this dike marks a great fault. I am rather surprised that it should not have been recorded before, as the evidence seems clear enough. The cornstones occur immediately to the north of it, while the marine limestones are only a few hundred yards south; so that this fault cuts off all the strata represented, along about two miles of shore on the northern section, *i.e.* from the cornstones north of the fallen rocks to the shepherd's house at Laggan, *i.e.* nearly all the Calciferous Sandstone series: a displacement which may be roughly estimated at about 300 fathoms.

The beds known as the Corrie Limestone consist of twenty-two beds of limestone, interstratified with beds of red shale; the total thickness of limestone being about twenty feet. These beds are referred to by Sir A. Geikie as follows (p. 801): "A band of marine limestone, lying in the red sandstone series in Arran, is crowded with ordinary Carboniferous Limestone shells, such as *Productus giganteus, P. semireticulatus, P. punctatus, Chonetes hardrensis, Spirifer lineatus*, etc."

The latter part of this quotation I very heartily endorse. The strata, consisting of sandstones, shales, etc., are mostly red. Even the limestone fossils are as red as the sandstones themselves. They are crowded with fossils; *Productus giganteus* exists here by the million. Owing to a great upthrow these same limestones appear on the northern flank of the hill called Maoldon.

Three other upthrows of the same limestone occur further to the south, but it is unnecessary here to refer to them. There can be no doubt that these are the same limestones, previously observed on the north shore, near the shepherd's house at Laggan. Generally speaking, the fossils are the same, as is also the character of the limestone and interbedded shale, in all but the colour.

There can be no question that the red colour is due to the presence of hematite iron-ore distributed through the strata, and many seams hold this mineral to such an extent as to soil the hands—which some of the fossils will do even after years of exposure to the weather. These ores also appear sometimes as seams of red ironstone, and at other times the ironstone is segregated into detached nodules or into nodular bands. Good examples of both kinds are to be seen in the old quarries, on the hills behind the village, and also on the shore at Corrie; but, although the prevailing colour is red, this is not by any means universal, and white sandstones are, and have been, quarried behind the village of Corrie, both above and below the limestones—*e.g.* in a quarry behind Corrie Hotel, where a white sandstone may be seen overlain by a bed of fireclay, containing the usual Stigmarian rootlets.

As has already been shown, the same limestone and shales and

sandstones, which are red at Corrie, are respectively black and white at Laggan: I submit that the redness is only a local peculiarity.

Taking up the quotation at the point left off, Sir A. Geikie writes (pp. 801, 828): "These fossils [*i.e. the limestone fossils*] are absent from the great series of red sandstones overlying the limestone, and do not reappear till we reach the limestones in the Lower Carboniferous series: yet the organisms must have been living during all that long interval outside of the Upper Old Red Sandstone area."

I admit that the limestone fossils are absent from the great series of red sandstones; but when Sir A. Geikie infers that these red sandstones contain Old Red Sandstone fishes, I can but ask for the production of even a single Old Red Sandstone fish from any part of the Island of Arran. That marine fossils should be "absent from the great series of red sandstones overlying the limestone" was to be expected, the fossils found in Carboniferous sandstones elsewhere being exclusively plant-remains, and I am only aware of one bed of sandstone in the West of Scotland containing marine remains, and that is in the Upper Limestone series.

Plant-remains are even commoner in Arran than I have seen them elsewhere, a fact already sufficiently recorded by previous writers, and which may be easily verified by anyone who walks along the shore at Corrie, where they protrude every here and there from the sandstone, while one sandstone intercalated between the limestones in front of Corrie Hotel is packed with rootlets of plants. Plant-remains are also abundant all along the northern sections and also towards the south in the cliffs of Maoldon.

(*To be continued.*)

V.—Woodwardian Museum Notes.

Notes on the Evolution of the Genus *Cheirurus*.

By F. R. Cowper Reed, M.A., F.G.S.

(*Continued from the March Number, page* 123.)

ALONG the branch which is marked earlier by *Cyrtometopus* and *Cheirurus* (*sens. str.*), the last stage of development corresponds with Salter's subgenus *Crotalocephalus*. This is almost entirely restricted to Devonian beds, but it is linked to *Cheirurus* (*sens. str.*) in time and zoological characters by *Ch. Sternbergi* (Boeck) and *Ch. Quenstedti* (Barr.), in which the glabellar side-furrows hardly meet in the middle of the glabella. The important subgeneric characters of *Crotalocephalus* are the continuous first and second side-furrows, the triangular basal lobes which nearly or quite meet in the centre of the glabella at their apices, and the nearly straight obliquely-directed third side-furrows of the glabella. The earlier forms of the subgenus have their triangular basal lobes still separated by a median portion of the glabella, as in *Ch. Quenstedti*, from Etage E. This species has a rather curiously specialized kind of pygidium, with only two pairs

of long spinose pleuræ; the third pair is very short and rudimentary, and of the fourth pair there is no trace. It is a noteworthy point that the pygidia of this subgenus are, as a rule, almost identical with those in the group of *Cheirurus* (*sens. str.*), with three equal pleuræ with free ends (*vide antea*), and do not show the enlargement of the first pair, as in the Russian *Cheirurus* (*sens. str.*).

The fullest development of the special features of this subgenus is found in the Devonian species, such as *Ch. gibbus* (Beyr.). The English forms are *Ch. Pengellii* (Whidborne) and *Ch. Sternbergi* (Boeck), from the Middle Devonian limestones. No members of the genus are known above the Devonian, so that stratigraphically, as well as in points of anatomical structure, *Crotalocephalus* is the highest in the series.

Returning now to the point where the main stem gave off the *Crotalocephalus* and *Pseudosphærexochus* branches, we find the latter branch arising from the neighbourhood of *Ch. claviger* (Beyr.) and leading first to the subgenus *Nieszkowskia*, which, by the number of its pleuræ (12) and the absence of a constriction on them, as well as by the presence of a row of puncta instead of a furrow, and the weakness of the fulcrum, shows the persistence of certain primitive characters, and its close connection with *Eccoptocheile*. But in the pygidium we find a very considerable amount of modification, and in fact *Nieszkowskia* shows a more specialized pygidium than any member of the whole genus. This indicates that the evolution of the different parts of the body did not proceed at equal rates; and we have seen throughout that the pygidium is the part which suffers the most diverse, irregular, and non-consecutive changes, being in one case of a reversionary type, while in a closely-allied species it has characters far in advance of the amount of specialization shown by the rest of the body.

In *Nieszkowskia* the pygidium possesses only two pairs of pleuræ, and these end in free points; the anterior pair is of huge size and usually three or four times as large and long as the posterior pair, which it completely embraces laterally.

The head-shield of this subgenus also shows a remarkable kind of development, for the glabella is inflated posteriorly and rises into a hump, or is produced into a spine. The side-furrows resemble those of its immediate predecessors, and the very forward position of the posterior branch of the facial suture, and the small free cheek, likewise recall the characters of *Eccoptocheile*. The type of the subgenus is *Ch.* (*N.*) *cephaloceros*, and Angelin's *Cyrtometopus tumidus* and *Cyrto. gibbus* also belong to it. *Nieszkowskia* occurs in the lower part of the Ordovician of Russia and Sweden.

The last stage of this line of development is shown by the subgenus *Pseudosphærexochus*, which in its glabella resembles *Sphærexochus*, though the basal lobe is not so strongly or so completely marked off. The posterior branch of the facial suture cuts the outer margin of the head-shield such a short way in front of the genal angle that it prepares us for the state of things in *Sphærexochus*, where the suture cuts the genal angle itself. The pleuræ, with

a nearly obsolete line of puncta or with a plain surface, likewise are preliminary to the smooth pleuræ of *Sphærexochus*. The presence of a distinct fulcrum is an advance on *Nieszkowskia* and the non-fulcrum-bearing pleuræ of *Eccoptocheile*. The four pairs of pleuræ to the pygidium with free ends are reversionary, and again point to the independent evolution and modification of the pygidium. In England the only species so far recognized are *Ps. conformis* (Ang.) and *Ps. subquadratus* (Reed MS.) from the Keisley Limestone, and *Ps. moroides* (Marr and Nicholson) from the Stockdale Shales.[1]

A small group of species, of which *Ch. octolobatus* (Salter) is an example, stands apart from those above described, by a combination of characters showing widespread and complex affinities. The smooth pleuræ and the glabellar furrows resemble those of *Pseudosphærexochus*, while the very small free cheeks and position of the facial suture ally Salter's species (*Ch. octolobatus*) with *Nieszkowskia*. But several features of the head-shield, pleuræ, and pygidium seem to link it to the Bohemian species *Ch. neglectus* (Barr.) and *Ch. completus* (Barr.) of Dd 5, and through them to the transitional forms between *Eccoptocheile* and *Cyrtometopus*.

The relationship of *Ch. trispinosus* (Young), of the Penkill mudstones of Girvan and the Silurian of Gothland, is doubtful; but its discoverer, Prof. Young, suggested that it might be necessary to create a special genus for its reception,[2] and Lindström[3] has recently done so, and placed it in a new genus, *Youngia*, along with two new Gothland species—*Y. inermis* (Lindstr.) and *Y. globiceps* (Lindstr.).

The American species of *Cheirurus* have not been taken into account in the foregoing sketch of the affinities and evolution of the species of the genus, because specimens of them are not sufficiently common nor their characters adequately known in this country to admit of speculations of any value.

Distribution in Space.

The theory of the existence of North and South European provinces for trilobites, at any rate during a great part of Lower Palæozoic time, seems to rest on a considerable accumulation of evidence, and in the case of *Cheirurus* we can clearly perceive several facts in its support.

Firstly, we find that the *Cyrtometopus* group attained a greater development in the north of Europe than in the south; its species were much more numerous and its diversity of form much greater.

Secondly, we find that southern Europe was characterized by the absence of the northern forms *Nieszkowskia*, *Pseudosphærexochus*, and *Sphærocoryphe*.

Thirdly, we find that the *Cheirurus* (*Eccopto.*) *claviger* group is confined to the south. This group of species contains the earliest members of the genus in Bohemia, and in that country alone a fairly

[1] Quart. Journ. Geol. Soc., vol. xliv, 1888, p. 722, pl. xvi, fig. 9.
[2] Young. Proc. Nat. Hist. Soc. Glasgow, 1868, I, pt. i, p. 171, T. i, figs. 4, 6*b*.
[3] Lindström. Förteckning pa Götland Siluriska Crustacéer, in Öfversigt Kongl. Vet. Akad. Förhandl. 1885, No. 6, p. 50, T. xiii, figs. 11, 12.

consecutive series of transitional forms can be traced upwards from it to *Crotalocephalus*.

The stratigraphical gap between Étages C and D in that area may account for the absence of the *Anacheirurus* and early *Eccoptocheile* forms.

In the northern province, on the other hand, the zoological hiatus occurs between the early *Eccoptocheile* and its nearest ally, *Nieszkowskia*, on the one side, and *Cyrtometopus* on the other side. The Bohemian *Ch. claviger* group supply the missing links, and we may not unreasonably suppose that there was some communication, if only occasional and intermittent, between the two provinces. The manner in which the *Cyrtometopus* branch is connected with the earlier forms of the whole genus seems to indicate this. It does not appear improbable that a few migrants of the *Ch. claviger* group wandered north from Bohemia, and, meeting with changed conditions and a new environment, developed rapidly into the peculiar northern species of *Cyrtometopus*, and branched off into the *Nieszkowskia*, *Sphærocoryphe*, and *Pseudosphærexochus* types; while their southern contemporaries and congeners, under less variable and more uniformly changing conditions, pursued the steady, undeviating march of direct development without giving off side-branches.

The physical or biological conditions of northern Europe, moreover, appear to have affected the pygidia in a special way, leading to the formation of the Cyrtometopian type, which is common to the majority of the northern species of the subgenus *Cheirurus*; while in Bohemia the same subgenus has pygidia closely resembling those of the ancestral *Eccoptocheile*. An intercommunication of the two provinces is suggested by the presence of some southern types in the north, especially in Great Britain, where the southern type of pygidium in the subgenus *Cheirurus* is predominant.

The subgenus *Crotalocephalus*, with its uniform characters throughout North and South Europe, appears to have had its birthplace in the southern province in Silurian times, and to be a direct offspring of the typical southern forms of *Cheirurus* (*sens. str.*). In the Devonian period it overspread the northern area as well, but did not suffer any further modification in spite of this enlargement of its area of distribution.

LIST OF PRINCIPAL EUROPEAN SPECIES OF THE GENUS *CHEIRURUS*.

Cheirurus (*Anacheirurus*, nom. prop.) *Frederici* (Salter). British only: Upper Tremadoc, North Wales.

Cheirurus (*Eccoptocheile*) *Sedgwicki* (Salter). British only: Llandeilo Flags, South Wales.

,, (,,) *claviger* (Beyrich).
,, (,,) *Guillieri* (De Tromelin).
,, (,,) *pater* (Barrande).
,, (,,) *marianus* (De Verneuil).
,, (,,) *perlata* (Hawle and Corda).
,, (,,) *curta* (Hawle and Corda).
,, (,,) *Durocheri* (Ronault).

Cheirurus (*Eccoptocheile*) *scuticauda* (Barrande).
,, (allied to *Eccoptocheile*) *insocialis* (Barrande).
,, (,, ,,) *gryphus* ,,
,, (,, ,,) *pectinifer* ,,
,, (,, ,,) *tumescens* ,,
,, (,, ,,) *comes* ,,
,, (,, ,,) *neuter* ,,
,, (,, ,,) *globosus* ,,
,, (,, *Cyrtometopus*) *neglectus* ,,
,, (,, ,,) *completus* ,,
,, (,, ,, etc.) *octolobatus* (M'Coy). British only: Bala.
,, (,, ,, ,,) *latilobus* (Linnarsson).
,, (*Cyrtometopus*) *clavifrons* (Dalman). ? British: Keisley Limestone,
,, (,,) *affinis* (Angelin). [Keisley, etc.
,, (,,) *Zembnitzki* (Eichwald sp.).
,, (,,) *verrucosus* (Brögger).
,, (,,) *longispinus* (Angelin).
,, (,,) *diacanthus* (Angelin).
,, (,,) *Plautini* (Schmidt).
,, (,,) *Rosenthali* (Schmidt).
,, (,, ?) *juvenis* (Salter). British only: Bala.
,, (*Hemisphærocoryphe*, nom. prop.) *pseudohemicranium* (Nieszkowski sp.).
,, (,, ,,) *aries* (Eichwald sp.).
,, (*Sphærocoryphe*) *cranium* (Kutorga sp.).
,, (,,) *platycranium* (Kutorga sp.).
,, (,,) *euurus* (Kutorga sp.).
,, (,,) *Hubneri* (Schmidt).
,, (,,) *granulatus* (Angelin).
,, (,,) *dentatus* (Angelin).
,, (,,) *unicus* (Wyville Thomson sp.). British only: Bala,
,, (*Nieszkowskia*) *cephaloceros* (Nieszkowski sp.). [Wales; and Girvan.
,, (,,) *tumidus* (Angelin).
,, (,,) *variolaris* (Linnarsson).
,, (,,) *Kochii* (Boll).
,, (,,) [= *Cyrtometopus gibbus* (Angelin)].
,, (*Pseudosphærexochus*) *hemicranium* (Kutorga sp.).
,, (,,) *conformis* (Angelin sp.). In Britain: Keisley Limestone, Keisley, and Chair of Kildare.
,, (,,) *Roemeri* (Schmidt).
,, (,,) *Pahnschi* (Schmidt).
,, (,,) *moroides* (Marr and Nicholson). British only:
,, (,,) *laticeps* (Linnarsson sp.). [Stockdale Shales.
,, (,,) *approximatus* (Eichwald sp.).
* ,, (,,) *subquadratus* (Reed MS.). Keisley Limest., Keisley.
,, (,, ?) *tenuispinus* (Linnarsson sp.).
,, (,, ?) *octacanthus* (Angelin sp.).
,, (,, ?) *Wegelini* (Angelin sp.).
,, (,, ?) *granulatus* (Angelin). (*Sphærexochus granulatus*.)

Group I, with Cyrtometopian pygidium.

,, (*Cheirurus*, sens. str.) *exsul* (Beyrich).
,, (,,) *gladiator* (Eichwald).
,, (,,) *macrophthalmus* (Kutorga).
,, (,,) *scutiger* (Eichwald sp.).
,, (,,) *spinulosus* (Nieszkowski).
,, (,,) *aculeatus* (Eichwald sp.).
,, (,,) *approximatus* (Eichwald sp.).
,, (,,) *glaber* (Angelin). In Britain: Keisley Limestone,
,, (,,) *ingricus* (Schmidt). [Keisley.
,, (,,) *ornatus* (Dalman).
,, (,,) *punctatus* (Angelin).
,, (,,) *speciosus* (Hisinger).

Cheirurus (*Cheirurus*, sens. str.) *Gotlandicus* (Lindström).
,, (,,) *propinquus* (Münster).
,, (,,) *subulatus* (Linnarsson).
* ,, (,,) *keisleyensis* (Reed MS.). Keisley Limestone.
,, (,, ?) *gelasinosus* (Portlock sp.). British only: Bala; [Girvan; and Ireland.
,, (,, ?) *Hawlei* (Barrande).
,, (,, ?) *conformis* (Angelin).

GROUP II.

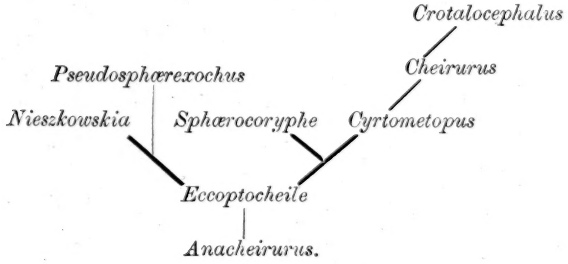
,, (,,) *bimucronatus* (Murchison sp.).
,, (,,) *bimucronatus* var. α, *bimucronatus* (Salter). British only: Bala to Ludlow.
,, (,,) *bimucronatus* var. β, *centralis* (Salter). British only: Bala to Ludlow.
,, (,,) *bimucronatus* var. *acanthodes* (Marr and Nicholson). Stockdale Shales.
,, (,,) *insignis* (Barrande).
,, (,,) *Quenstedti* (Barrande).
,, (,,) *Quenstedti* var. *præcursor* (Frech).
,, (,,) *Beyrichi* (Barrande).
,, (,,) *brevimucronatus* (Münster). ? Ireland; Bala.
,, (,,) *obtusatus* (Corda).
,, (,, ?) *cancrurus* (Salter). British only: Bala.
,, (,, ?) *bifurcatus* (Barrande).
,, (*Crotalocephalus*) *Sternbergi* (Boeck). Middle Devonian, Lummaton.
,, (,,) *Sternbergi* var. *interrupta* (Kayser).
,, (,,) *gibbus* (Beyrich).
,, (,,) *gibbus* var. *interrupta* (Barrande).
,, (,,) *pauper* (Barrande).
,, (,,) *myops* (Roemer).
,, (,,) *articulatus* (Münster). ? British. Devonian.
,, (,,) *Lenoiri* (Bergerson).
,, (,,) *Pengellii* (Whidborne). British only. Mid. Devonian.
,, (,,) *Cordai* (Barrande).

DOUBTFUL POSITION.

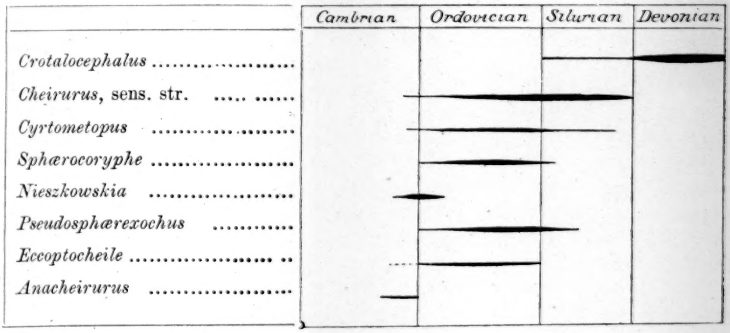
Cheirurus fortis (Barrande).
,, *vinculum* (Barrande).
,, *radiatus* (Barrande).
Cheirurus minutus (Barrande).
,, *dubius* (Pompecki).
,, ? *decacanthus* (Angelin).

* The description of these new species will shortly be published.

GENERAL SCHEME OF RELATIONSHIP OF SUB-GENERA OF *CHEIRURUS*.



GENERAL RANGE OF SUB-GENERA OF *CHEIRURUS* IN TIME IN EUROPE.



VI.—The Altered Clastic Rocks of the Southern Highlands, their Structure and Succession.

By Peter Macnair.

I. Introductory.

In the following paper I propose to give an account of some observations upon the structure and succession of the rocks of the Southern Highlands. By the term Southern Highlands I mean that part of the Scottish Highlands lying immediately to the north-west of the great line of fault separating the older rocks of the former area from the younger Old Red Sandstone series of the low grounds.

The more detailed stratigraphical part of the work which I have been enabled to undertake has principally been confined to the central parts of Perthshire, and the sections illustrative of the structure of the Southern Highlands will be principally drawn from that source. But it will be evident to anyone upon the inspection of a geological map that such sections will be more or less typical of the whole series, seeing that the rocks strike in such a prevalent north-east and south-west direction across the whole country.

The principal object of the paper, then, will be to give an account of the altered clastic rocks of the district, only mentioning incidentally, and where it is necessary for making the sections clear, the occurrence of igneous rocks. The nature of these clastic rocks as altered sediments has now been long known, but the more difficult points involving their structure, succession, and relationships have not been at all understood; and it is to these, then, I would more particularly draw your attention, trusting to be able to throw some light upon the somewhat obscure and difficult subject.

II. Work of Previous Observers.

Before passing to the more immediate subject of the paper, I would here briefly refer to the work of some of the previous observers upon this district, and that for a more particular reason, namely, that justice may be done to one of the most illustrious names connected with Scottish geology, I mean James Nicol, whose knowledge of the Highland rocks and abilities as a stratigrapher was far in advance of his time.

In the years 1860–1 Murchison and Geikie,[1] and also R. Harkness,[2] published papers dealing with certain traverses of the Southern and Central Highlands. These papers were naturally based on the supposed succession in the north-west of Sutherlandshire, so that their observations were no doubt to a great extent overshadowed by it, Murchison and Geikie being of course predisposed to the old theory, so that they saw nothing in these traverses but what conformed to it, and that, simply put, was that all the rocks below any limestone band were quartzose and flaggy, and represented their lower series, and all above it were micaceous and schistose, and representing their upper series; though the latter seems to have had serious doubts on the matter, not being able to make nature fit the theory, the consequences of the whole being that the true mineralogical character of the beds and their stratigraphical succession escaped them.

The paper of Harkness bears upon itself such evident misconception of the mineral characters of the Highland rocks, which had already been established by such observers as Maculloch, as to render it entirely worthless from a geological point of view. For instance, a comparison of the description of the Pass of Leny section with that given by Nicol the following year, shows clearly the difference in value of the two observers' work.

Turning now to Nicol's paper,[3] published in 1862, we find it thoroughly characteristic of the man. His reading of the sections are simple descriptions of what he saw in nature. At the outset he states the object of his paper, which was to investigate the relationships of the three great formations, the clay-slate, the mica-slate, and the gneiss; and though he seemed to be burdened with the Wernerian doctrine of their succession, yet his paper seems to me to show his masterly conception of what the unravelling of the Highland rocks meant. The manner in which he chose his sections, and the faithful description he gave of their rocks, are scarcely surpassed by those of the Geological Survey of the present day, who have adopted much the same methods in attacking the Highland problem. His method was to take a series of sections at different points from east to west across the Highlands from the verge where they abut against the Old Red Sandstone, explaining their principal mineral

[1] "Altered Rocks of the Central Highlands": Quart. Journ. Geol. Soc. 1861.
[2] "On the Rocks of Portions of the Highlands of Scotland": Quart. Journ. Geol. Soc. 1861.
[3] "Southern Grampians": Quart. Journ. Geol. Soc., vol. xix, p. 180.

and stratigraphical features. He noticed in all his sections the occurrence in regular order of clay-slates, grits, greywackes, and mica-schists. He also noticed the reversal of dip from south-east to north-west as he proceeded from west to east across the Grampian range. His final conclusion, however, as to the south-east being the normal dip, and the clay-slates consequently being the highest members of the series, while the north-westerly dip and consequent infraposition of the slates was owing to a reversal of the normal order, seems now to have been incorrect, and was probably owing to his strong Wernerian leanings. After the publication of these papers little or nothing seems to have been done in the investigation of these rocks. The great name of Murchison and the assent of such men as Harkness, Ramsay, and Geikie swayed the scientific world, and Nicol and his papers, both on the North-west and Southern Highlands, were soon forgotten. However, time and the unchanging mountains, in whose hands this great geologist had to leave his cause, eventually proved the truth of his observations and deductions. Afterwards the work of Dr. Callaway and Prof. Lapworth in the north-west re-awakened interest in the problem, the results being the final establishment of the essential principles arrived at and maintained by Prof. Nicol.

In a brief summary of the rocks of Highland Perthshire,[1] by Mr. H. Coates, F.R.S.E., and myself, published in 1891, we gave a table of the succession of the Highland rocks, which, though not so much in detail, was practically the same as that given at the end of this paper, and similar to the succession afterwards given by Sir A. Geikie as the work of the Geological Survey in his Presidential Address to the Geological Society, the great argillaceous, arenaceous, and limestone zones being then marked out as follows, in a descending order :—

6. Quartzites, grits, greywackes, and other arenaceous rocks.
5. Mica-schists, quartz-schists.
4. Calcareous mica-schist and pure limestone.
3. Mica-schist and quartz-schist in varying proportions.
2. Quartzite, grit, greywacke, and conglomerate.
1. Clay-slates, phyllites, and other argillaceous rocks.

In the explanatory note accompanying his geological map of Scotland,[2] published 1892, Sir A. Geikie gives a brief summary of these rocks, using the term Dalraidian to define them, as he had previously proposed in his Presidential Address.[3] He again refers to the occurrence of annelid tubes in the quartzites, but does not give their localities or horizons, and whether they are identical with those described by the Duke of Argyll[4] and the author[5] in 1889 I am unable to say.

[1] Transactions Perthshire Society of Natural Science, vol. i, p. 221.
[2] Explanatory Notes to Geological Map of Scotland, p. 8.
[3] Presidential Address, Quart. Journ. Geol. Soc., vol. xlvii, 1891.
[4] "Bodies of Organic Origin": Roy. Soc. of Edinburgh, 1888–9, p. 40.
[5] Trans. Perthshire Soc. of Nat. Science, vol. i, p. 116.

In the last edition of his textbook,[1] published 1893, Sir A. Geikie gives a short account of the work of the Geological Survey amongst the rocks of the Central and Southern Highlands. He there says it is deserving of remark that the rocks along the southern margin of the Highlands are for the most part so little affected as closely to resemble portions of the unaltered Silurian series of the South of Scotland, and that they dip towards the mountains, being more highly foliated and crystalline as they recede from the Lowlands. This may be practically said to be all that is at present known of the stratigraphical affinities of these rocks, a fact which was pointed out nearly fifty-one years ago by James Nicol; and from this fact, with his description of the Southern Highlands and his theory of the north-west, taken together, it will be found that, generally speaking, our knowledge of the geological structure of the Scottish Highlands has not much advanced beyond where Nicol left it. It is quite evident from his writings that he saw clearly the fallacy of Sir R. Murchison's observations and deductions as to the supposed north-west succession, and this being so it left him untrammelled in his descriptions of the other parts of the Highlands, so that we find them, as I have already said, perfect transcriptions of what he saw in nature. He states his position on this point very clearly in the conclusion of his famous paper.[2] There is no evidence, he says, to connect the great mass of crystalline schists, stretching from the north coast of Sutherland to the south of Inverness-shire, more closely with the mica-slates of Ben Hope than with the gneiss of Scourie Loch, Inver, and the Gairloch, or to justify us in throwing aside mineral characters for some assumed synchronism in the age of the original but now wholly altered deposits.

III. Lower Argillaceous Zone.

At the end of the paper I have bracketed together into zones and given in the form of a table the chief rock groups occurring in the Southern Highlands. Perhaps a word explaining the table would be of advantage here. The table is a descending one, the highest rocks being placed at the top, the lowest at the bottom. They have been grouped together into zones under their larger lithological features, which will be found to be more or less characteristic of each rock-bed. As I mentioned before, these zones have principally been determined from sections in Perthshire, but they undoubtedly range across the country from shore to shore in a succession similar to that occurring in Perthshire. The lowest member of the series (the lower argillaceous zone) given in my table is one whose lithological features are so well known as scarcely to need description. Outcropping at almost the base of the exposed rocks of the Southern Highlands, it strikes across their flanks from north-east to south-west. It does not, however, mark

[1] Textbook of Geology, 3rd edition, pp. 627, 708.
[2] "North-west Highlands": Quart. Journ. Geol. Soc., vol. xvii, 1860.

the real base of the system, that being covered by the later overlapping Old Red Sandstone series, the clay-slates often being seen to pass downwards before plunging beneath the Old Red Sandstone basal conglomerates into grits and greywackes similar to those which overlie it. These argillaceous rocks are therefore intercalated between the grits, greywackes, and conglomerates of the lower arenaceous group, and represent a period of sedimentation, during which the land-surface had reached a maximum of depression beneath the waters of the ocean.

The principal rocks of this zone are clay-slates, phyllites, black shales, and limestones, the typical rock of the whole being the clay-slate, which is simply a highly indurated mud upon which a fine fissile structure has been superinduced by metamorphism. As a rule, the cleavage of these rocks coincides with their bedding; this is shown by the manner in which these slates are intercalated between the bedding planes of the grits and conglomerates of the arenaceous zone. There is, therefore, seldom evidence of any more than the one set of divisional planes. Occasionally, however, evidences of other divisional planes cutting across the former are to be met with.

Sometimes the clay-slates pass into a fine lustrous or micaceous variety, to which the term phyllite has been applied. These phyllites seem to me to be simply further stages in the process of metamorphism, and probably link the clay-slates with such highly foliated crystalline rocks as the sericite schist of Ben Lawers. These phyllites show an occasional tendency to foliation, as seen in the beds above Loch Lubnaig.

Towards the north-east this argillaceous zone, which is thus found to form the outer edge of the Southern Grampians, dips inwards, and is seen to be overlain by the main mass of the Grampian range. On tracing this zone, however, towards the south-west, a gradual reversal of the dip towards the south-east is seen to occur. It will be evident, however, from sections to be described, that the order occurring in Perthshire and further to the north-east is the normal order, while that seen at Loch Lomond and further westwards represents a reversal of the beds. Black graphitic shales are also to be met with upon this horizon, though they do not seem to be as extensively developed as in the upper argillaceous zone, which will be noticed later on.

Limestone is also to be found on this horizon, as at the Pass of Leny, above Kilmahog old toll-house, which will be described in the Pass of Leny section. I am also led to understand that it has been seen further to the east, near Birnam.

IV. Lower Arenaceous Zone.

Underneath and immediately above the lower argillaceous zone just described we find a series of rocks, varying from a fine-grained greywacke, through quartzites and grits, to coarse conglomerates, to the whole of which, taken together, we have given the name lower arenaceous zone. As before remarked, the lower argillaceous zone is intercalated between these rocks, and is seen at some places

to pass downwards into them, though they are soon covered by the later Old Red Sandstone conglomerates. Above the argillaceous zone, however, a strong and constant band of these arenaceous rocks is well developed. Along the shores of Loch Lomond they are to be seen below Rowardennan, being also well exposed near Sallachie Wood, from whence they strike northwards, being well developed along the northern shores of Loch Katrine. Still further eastwards, massive beds characteristic of this zone are seen in Ben Ledi; passing further along the line of strike, they are shown in Ben Vorlich, around St. Fillans, in Glen Leadnock, thence by Dunkeld Bridge of Cally, and onwards to the sea above Stonehaven. The rocks of this lower arenaceous group are easily recognized by their scarcely altered fragmental aspect, showing little or no evidence of the intense metamorphism which is to be found nearer the centre of the Highland area. They have, of course, been more or less indurated, but they rarely show such evidences of extreme crystallization and foliation as are to be found amongst some of the higher zones to be described. The rocks of this zone vary from exceedingly fine light or dark greywackes (which are hardly to be recognized from an igneous rock, so fine is their texture through grits, with their pebbles of quartz and felspar set in a fine matrix of comminuted felspathic matter) to massive conglomerates with pebbles, often as large as an inch and more in diameter. These fine-grained greywackes often exhibit a closely banded structure of lighter and darker shades of grey, which is undoubtedly referable to the original sediments out of which the beds have been formed.

V. Middle Arenaceous Zone.

The next zone in ascending order is that to which we have given the name middle arenaceous zone, because it is found to lie between the lower arenaceous group just described and an upper argillaceous and arenaceous zone, from both of which it is easily distinguished by its lithological features. Intercalated in this group occurs the Loch Tay limestone zone, about to be described.

The characteristic rocks of this middle arenaceous group are a series of mica-schists, quartz-schists, and grits. They are more highly foliated than the arenaceous groups below, and seem to have suffered a further degree of metamorphism. Upon the whole, they seem to present more of an arenaceous than an argillaceous affinity, they being easily distinguished, as I have already remarked, from the arenaceous band below. Geographically, they extend in a broad band across the country in a similar manner to those zones just described, occupying the region between the lower arenaceous group on the south and the upper argillaceous zone on the north. They are well exposed in the valley of the Dochert, the braes of Balquhidder, also on the hills that lie between Loch Earn and Loch Tay, stretching north-eastwards by Aberfeldy, Pitlochry, and thence onwards into the Eastern Grampians, where they seem to have been largely displaced by the later eruptive masses of granite and other igneous rocks.

The quartz-schists and mica-schists of this zone represent between their two extremes an infinite variation of their two constituent minerals—mica and quartz. The quartz-schists seldom, however, lose so much of their mica as to approach the typical quartzites of the lower zone, while the mica-schists, on the other hand, rarely become so argillaceous as to approach the finely foliated mica-schist of the upper argillaceous series. Both the micaceous and quartzose varieties are often highly charged with garnets, as in and around both Loch and Strath Tay.

The grits of this series, like the other members just described, show a more distinct tendency to foliation than those belonging to the lower series, the finer matrix in which the pebbles of quartz are imbedded becoming more or less foliated, and wrapping each individual pebble in a series of plates of mica, giving the rock somewhat of a gneissose aspect. The larger pebbles of quartz show evidence of having been drawn out along the lines of shear, and look more like veins of segregation than original quartz pebbles.

VI. The Loch Tay Limestone Zone.

The next zone which falls to be mentioned is that of the Loch Tay limestone, which, as we have already noticed, is found intercalated in our middle arenaceous group, the quartz and mica-schists of the latter being found both to underlie and overlie the band of limestone. The rocks of this zone are not always pure limestone, but often pass into a calcareous mica-schist, the whole pointing, as in the lower argillaceous zone, to the land-surface having reached a maximum of depression below the level of the sea. Below this limestone band and upon this horizon occur massive beds of sheared basic rocks, which follow the limestone in a remarkable manner; wherever it is found, in fact, they may be said to be coextensive with the limestone from the east to the west coast across the whole of the Southern Highlands. They are evidently basic igneous rocks which have been intruded into the schists and limestones at a period prior to their metamorphism, and which have subsequently undergone the same shearing process as the clastic rocks, being now structurally identical with the schists.

The Loch Tay limestone has been traced by the officers of the Geological Survey from shore to shore across the Southern Highlands, through the shires of Banff, Perth, and Argyll. In Perthshire, where I have principally been enabled to trace its outcrop, it is found to extend from Crianlarich in the east, down the north side of Glen Dochert to Killin, and thence north-eastwards by Loch Tay to Fernan, where it is abruptly cut off by a fault. It does not seem to appear again in Strath Tay, but after passing Strath Ardle it appears again at Ashintully, Kirkmichael, and Mount Blair.

VII. The Upper Argillaceous Zone.

The upper argillaceous zone, which I have given as succeeding the higher members of the middle arenaceous group, is characterized by a series of highly altered argillaceous rocks, the principal

member of which is a fine sericite schist, occasionally becoming calcareous with subordinate beds of finely banded greywackes and quartzites, both of which contain traces of annelid burrows. The other member of this zone is a fine black graphitic schist, which occurs upon a horizon higher than the sericite schist, and marks the top of this group. Like the other calcareous and argillaceous zones, it seems to represent a maximum of depression beneath the waters of the ocean.

The traces of annelid tubes which have been found in this zone were discovered by the Duke of Argyll[1] and myself,[2] His Grace finding his specimens behind the castle at Inverary, my own being found on Craig Na Challeich, a mountain above Killin, Perthshire. The beds in which the Duke found his specimens are described by him thus: "The comparatively thin beds in which the annelid tubes are found at Inverary are by no means the lowest in our series. They are underlain and overlain by a great number of beds, both slaty and siliceous, but the great mass is slaty, with a highly developed micaceous character." The annelid tubes were thus found in a thin band of quartzite, intercalated in a series of highly micaceous schists, which exactly corresponds to the character of the rocks where I found my own on Craig Na Challeich—that is, in the upper argillaceous zone. Further, in his map of Scotland, published in 1892, Sir A. Geikie[3] colours the rocks in which His Grace found his specimens as the same as those occurring on Craig Na Challeich, so that I have no hesitation in believing them to be the same beds, and that these annelid tubes mark a distinct horizon in these Highland rocks.

This zone, like the others just described, is found to have a similar geographical distribution across the whole of the Southern Highlands. In Perthshire I have traced it at Tyndrum, where it is faulted against a series of quartzites. Further east, on the high ridge above Loch Tay, it is found occupying its normal position above the middle arenaceous group, stretching through the peaks of Craig Na Challeich, Ben Cruben, Ben Lawers, and thence eastwards by Killiecrankie and the Spittal of Glenshee.

(*To be continued.*)

REVIEWS.

I.—Memoirs of the Geological Survey of Scotland: Explanation of Sheet 5. By John Horne, F.R.S.E.; with the collaboration of B. N. Peach, F.R.S., and J. J. H. Teall, F.R.S. (Edinburgh: printed for Her Majesty's Stationery Office by Neill & Co., 1896. 8vo, pp. 71, with 5 illustrations. Price 1*s.* 6*d.*)

SHEET 5 of the Geological Survey Map of Scotland includes a large portion of Kirkcudbrightshire, being the country around Castle Douglas, Dalbeattie, Kirkcudbright, and Gatehouse-of-Fleet.

[1] "Bodies of Organic Origin": Roy. Soc. of Edinburgh, 1888-9, p. 40.
[2] Trans. Perthshire Soc. of Nat. Sci., vol. i, p. 116.
[3] Map of Scotland, 1892.

Geologically the area is of considerable interest: it embraces a portion of the Southern Uplands, with rocks ranging in age from Arenig to Ludlow, Old Red Sandstone, and Carboniferous, to say nothing of Glacial Drifts and more recent deposits. It includes, moreover, various interbedded and intrusive igneous rocks, notably the great granite area of Criffel, with its fringe of metamorphic strata. The map has long been published, for the area was surveyed geologically nearly twenty years ago by Messrs. John Horne, D. R. Irvine, and C. R. Campbell, and of these Horne alone remains to tell the story of the work.

The delay in the issue of the descriptive memoir was caused, as we are told by the Director-General, by the publication in 1878 of Prof. Lapworth's classic memoir on "The Moffat Series," a work which rendered it desirable to again examine the area by "the light of his researches, which had at last supplied, in the zonal distribution of the Graptolites, a clue to the unravelling of the complicated structure of the Southern Uplands." This revision has now been accomplished, partly by Mr. Horne, partly by Mr. Peach, Mr. Macconochie, and Mr. Teall, with the personal aid of the Director-General.

The explanation is of far more than local interest, although it is strictly confined to a consideration of the phenomena observed in the district. The subject of contact-metamorphism does not appear to be dealt with at all fully, the matter being reserved for a promised general Memoir.

While the elaborate work of Professor Lapworth furnished the key for the interpretation of the complicated stratigraphy of this Palæozoic region, some considerable additions to our knowledge have been made during the course of the re-examination of the district by the Geological Survey. The existence has been ascertained of lavas, tuffs, and agglomerates in the Arenig group, and also of a well-marked and persistent horizon of Radiolarian cherts and mudstones in the upper portion of this volcanic series. Although only about 60 or 70 feet thick, these cherts appear to represent the whole succession of deposits which elsewhere in Britain intervene between the Middle Arenig and uppermost Llandeilo strata.

Interesting nodules composed of oxides of iron and manganese have been found in the Arenig mudstones, and Mr. Teall infers that "the rock was originally a limestone, that it was subsequently changed to a carbonate of manganese and iron, and, finally, that the carbonate was decomposed under oxidizing conditions so as to give rise to the nodular masses of the oxides of manganese and iron."

The various strata and their fossils, up to the top of the Silurian, are duly noticed, and the igneous rocks are then described.

The Upper Old Red Sandstone, poorly developed, consists of red sandstone, red clays, and cornstones, which underlie the volcanic group that forms the commencement of the Calciferous Sandstone Series. This Carboniferous group comprises sandstones and shales with marine bands surmounted by coralline limestone.

The Glacial Drifts are well represented, and proof is given that

the ice which drained from the inland country was in mass sufficient to override Criffel, and must therefore have had there a minimum thickness of 2000 feet—a fact of considerable interest in connection with the wide dispersal of boulders of Criffel granite.

Raised Beaches, Caves and Cavern Deposits, Peat and Alluvium, and Economic Products are duly mentioned.

Considerable interest naturally attaches to the large granite mass which covers upwards of seventy-five square miles of ground. The granite and its apophyses traverse strata of Llandovery, Wenlock, and Ludlow age; but the intrusion of the igneous complex must be older than the Upper Old Red Sandstone. Though mainly massive in character, yet in certain limited tracts along its margin the granite has a marked foliated character, and evidence is given to show that this foliated structure has been produced by mechanical deformation which has simultaneously affected, not only the main body of the granite, but also the basic inclusions which this rock contains, as well as the acid and even the quartz veins that traverse it. It is pointed out that the quartz and alkali-felspar, which were the last constituents of the granite to solidity, are those which have yielded most in the deforming stresses; while the fact that the foliation in the acid veins has no reference whatever to the direction which they take, is stated by Mr. Teall to be a striking proof that it cannot be due to fluxional movement during intrusion.

Dykes of porphyrite occur not only in the sedimentary rocks but also in the granitic masses. It is pointed out that the term "porphyrite" has hitherto been employed in a different sense by the Geological Survey, for certain lavas which occur in association with Palæozoic sediments, and which in reality are merely altered andesites. The present usage of the term is that adopted by Prof. J. P. Iddings for rocks of the type under consideration, which occur as sills and laccolites as well as dykes.

A detailed list is given of the rocks examined under the microscope, with their localities, and with remarks on their mineral structure.

We may add that the printing by Messrs. Neill and Co. compares so favourably with that noticed in a recent Survey Memoir printed in England, that we wonder H.M. Stationery Office does not have all its printing done in Edinburgh.

II.—Petroleum. By Boverton Redwood, F.R.S.E., assisted by Geo. T. Holloway and other contributors. Two Vols. 8vo. pp. 900. (London: Charles Griffin and Company, 1896.)

THIS comprehensive treatise is in every way creditable to both author and publisher: it has been prepared with care and skill, printed in clear and varied type, and provided with numerous illustrations. Its two volumes together comprise no fewer than 900 pages; there are 327 figures in the text; two frontispieces show respectively the distribution of petroleum throughout the world, and the appearance of the flame-caps corresponding to six different

proportions of admixed pentane and air; fifteen large plates illustrate the distribution in various oil-fields, sections of typical wells, and apparatus used in the industry. Reference to the detailed work is greatly facilitated by a table of contents extending over eleven pages, and by a copious index of twenty-six.

No one could be better qualified than Mr. Redwood for the preparation of such a treatise: for a quarter of a century he has had a consulting practice in connection with the petroleum industry; he is consulting adviser to the Corporation of London under the Petroleum Acts, and chemical adviser to the Oil Trade Section of the London Chamber of Commerce; he has visited the principal oil-fields and refineries of the world; and has made a special study of the numerous methods which have been devised for testing the various commercial products. But, as Mr. Redwood points out, the task of preparing a work satisfactory to himself would have been insuperable but for the practical help given to him by many friends, more especially by Mr. George T. Holloway, to whom he expresses his great indebtedness for assistance in the preparation of the matter for the Press, and in the toilsome revision of the proofs.

In the short space to which this notice is necessarily limited, it is impossible to do sufficient justice to the labour devoted to the preparation of the treatise, or to the skill with which the vast amount of information has been classified and made readily accessible. A brief statement of the contents, however, will give a good idea of the scope of the book. The first section (31 pages) deals with the history of the petroleum industry, beginning with accounts of occurrence and modes of collection placed on record by Herodotus, the Father of History, 2300 years ago; the history of the development of the industry in each of the countries of the world is then briefly sketched. Here are mentioned facts, the records of which are as impressive as fairy tales—fountains which have yielded £11,000 worth of oil daily, or which have shot up hundreds of feet high, carrying away the machinery used in the drilling of the well. The second section is the most extensive in the book (144 pages), and treats of the geological distribution of petroleum: the three theories of the cause of the pressure—overlying strata, water, accumulated gas—are first discussed; then follow descriptions of the geological peculiarities of the various oil-fields of the world. The manuscript of this section was revised by the late Mr. William Topley, F.R.S., who had given much attention to the subject, and whose early death all geologists deplore. The third section (53 pages) gives an account of the chemical and physical characters of petroleum, and contains many valuable tables. The fourth section is very brief (13 pages), and deals with the origin of this natural product: the author points out that the theories which regard petroleum as resulting from the decomposition or distillation of animal remains are now largely accepted by chemists. The fifth section (70 pages) relates to the winning of petroleum, and gives a detailed description of the apparatus used for the purpose in different countries. Section VI is a very important one, extending

to nearly 100 pages, and gives an account of the different methods which have been devised for the refining of the crude natural products. Section VII (63 pages) treats of the Shale-oil and allied industries. Section VIII (also 63 pages) describes the methods of transport, storage, and distribution: it is interesting to read, for example, that one line of pipes—the Emery (United States) Line—is 488 miles long. Section IX is another most important chapter, and one in which the experience and special knowledge of Mr. Redwood is manifest: it treats of the testing of the raw material and manufactured products. The next section (73 pages) gives an account of the uses of petroleum and its products; and the last one (86 pages) collects together the statutory, municipal, and other regulations adopted by various countries relative to the testing, storage, transport, and uses of petroleum. The work is then rounded off with 50 pages of statistics.

It is evident that Mr. Redwood's treatise will long be the standard work on this important subject.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—Annual General Meeting.—February 21st, 1896.

Dr. Henry Woodward, F.R.S., President, in the Chair.

The Secretaries read the Reports of the Council and of the Library Committee for the year 1895. In the former the Council again congratulated the Fellows on the satisfactory condition of the Society's finances, and announced that the decrease in the number of Fellows, to which attention had been drawn in the three previous annual reports, had now been all but arrested.

During 1895 the number of Fellows elected was 43; of these 32 qualified before the end of the year, making, with 12 previously elected Fellows, a total accession of 44 during the twelvemonth. In the same period the losses by death, resignation, and removal amounted to 45, the decrease in the number of Fellows being 1. The total number of Fellows, Foreign Members, and Foreign Correspondents was 1318 at the end of 1895, as compared with 1321 at the end of 1894.

The balance-sheet for the year 1895 showed receipts to the amount of £3249 13*s.* 4*d.*, and an expenditure of £2398 5*s.* 11*d.*, the excess of actual income over expenditure being £492 18*s.* 4*d.* Certain of the stocks belonging to the Society and to the Wollaston, Barlow-Jameson, and Bigsby Trusts were sold out, and re-invested in equally sound securities bearing a higher rate of interest.

The completion of vol. li of the Quarterly Journal was announced, as also the publication of No. 2 of the Record of Geological Literature added to the Society's Library. The Index to the first fifty volumes of the Quarterly Journal will, it is hoped, be issued to the Fellows in the course of the present year.

The question as to the desirability of retaining the Society's Museum had formed the subject of long and earnest deliberations by the Council, and, in accordance with the report of a Special Committee, the Trustees of the British Museum had been asked whether they would undertake to house and care for the collections, keeping type-specimens and specimens illustrative of papers read before the Society distinct, defraying also the expenses of transference. To these conditions the Trustees had assented, and the matter will no doubt before long be submitted to the Fellows for their decision at a special general meeting.

The proposed introduction of the electric light and redecoration of the Society's apartments was briefly referred to; and, in conclusion, the awards of the various medals and proceeds of donation funds in the gift of the Society were announced.

The report of the Library Committee enumerated the large additions made during the past year to the Society's library, and stated that the manuscript card catalogue of the geological maps and sections was now practically completed.

In handing the Wollaston Medal to Sir John Evans, K.C.B., D.C.L., F.R.S., F.L.S., Foreign Secretary (for transmission to Eduard Suess, Ph.D., For.Memb.R.S., For.Memb.G.S., Professor of Geology in the University of Vienna), the President addressed him as follows:—Sir John Evans,—

May I request you, in your official capacity as Foreign Secretary, to receive and transmit to our esteemed Foreign Member, Prof. Eduard Suess, of the University of Vienna, this Medal, founded by that eminent man, Dr. Wollaston, in 1828, "to promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country, by whom such researches may hereafter be made." Of the 27 occasions on which this Medal has been transmitted to foreigners, it has twice before been awarded to Austrian geologists, namely, in 1857, to the illustrious Barrande, and in 1882, to Franz Ritter von Hauer, Intendant of the Imperial Museum of Natural History in Vienna and Director of the Geological Survey of Austria.

In speaking of a man so well known as Prof. Suess, words of commendation on my part are hardly needful. For 39 years he has occupied the Chair of Geology in the University of Vienna, and has exercised an influence on the work of the distinguished school of geologists in that city—including such men as Neumayr, Mojsisovics, Fuchs, Waagen, Penck, and many others—which proves him to be a great master of our science. Since 1851 a steady stream of memoirs, issued by him, has proved him to be a great worker in geology; while the intellectual stimulus of his writings on foreign geologists shows him to be a great thinker. He is worthy of this award, therefore, not only for the work which he has accomplished himself, but by what he has roused others to do, not only by the originality of his own thought, but by the extent which he has influenced the mind of others.

Suess is not a specialist. He began work on Graptolites; he next laid the foundations of the modern classification of the Brachiopoda and Ammonites. Alpine problems roused his interest in dynamical and structural geology, and led to studies of the Austrian and Italian earthquakes, and to his suggestion of the connection between these and the great circle of European Tertiary volcanoes and the elevation of the Alps. Work on the complex Tertiaries of the Vienna Basin and a study of the Mediterranean littoral geology led to his researches in Faunistic Palæontology, and so prepared the way for his pupil Neumayr.

Suess's varied knowledge, penetrative insight, and suggestive originality are perhaps best exhibited in his "Antlitz der Erde," wherein he tried to show the main factors and methods that have ruled in geographical evolution.

The intimate union thus established between the problems of geology and

geography cannot but be regarded as of the highest importance to the advancement of both sciences, and the world has been made wiser by the rich stores of knowledge which Prof. Suess has garnered for geologists and geographers in all countries.

Prof. Suess has been connected with this Society since 1863, in which year I made his personal acquaintance when he visited London He has now been a Foreign Member since 1876, and is one of the three oldest foreign geologists on the Society's list. His attachment to this country will be better understood when it is known that Prof. Suess was born in London on the 20th of August, 1831, his father being at that time a merchant in the City.

I am sure it will add to Prof. Suess's pleasure to be told that this Medal was awarded him by the unanimous vote of the Council, and that we send with it our warmest remembrances and good wishes for his continued health and prosperity.

Sir John Evans, in reply, said :—Mr. President,—

The recipient of this award, whose professorial duties as well as his advancing age prevent him from attending this meeting, has requested me to read the following communication from him:—"By adding my name to the list of those masters of geological science who have been honoured before me by the award of the Wollaston Medal, your illustrious Society renders me truly proud, and I can hardly find words adequate to express my feelings of gratitude.

"In addition to field-work, I have for many years laboured to obtain some approximately comprehensive view of the surface-structure of the whole of our planet, and during this endeavour not a day has passed without bringing again and again before my eyes the vastness of the British Empire, the worldwide activity of British geologists and travellers, and the enormous amount of geological work and learning recorded in the English language.

"I often and gladly remember the kindness and the instruction which during the course of my life I have received from my English masters, and above all from my repeated intercourse with Sir Charles Lyell, but I dared not think that my own modest essays would ever be deemed worthy of this distinction—the highest that English geologists can bestow.

"This, however, now comes to me at an age when the natural diminution of physical strength confines me to valley and home; hammer and belt rest on their peg, and dreams and remembrances alone still carry me along those Alpine wanderings which form the highest charms of our incomparable science, and in the lonely grandeur of which Man feels himself more than ever a child of surrounding Nature.

"In these hours of enforced inactivity, the award of your Society leads me to hope that my past exertions have not been quite in vain; and with deepest thanks I receive this Medal as a token of indulgence, of encouragement, and also of consolation."

The President then presented to Alfred Harker, Esq., M.A., F.G.S., of the Geological Survey of Scotland, and of St. John's College, Cambridge, the balance of the proceeds of the Wollaston Donation Fund, addressing him as follows:—Mr. Harker,—

The Council request your acceptance of the Wollaston Fund in recognition of the admirable work in Petrology and your studies in the Metamorphic and Igneous Rocks and in Dynamometamorphism, to which you have given such careful attention since you joined our ranks as a Fellow in 1884.

I have only to allude to your papers before this Society on the Gabbro of Carrock Fell and its Granophyres; your petrological notes on rocks from the Cross-Fell Inlier; your paper on the eruptive rocks of Sarn, Caernarvonshire; your joint papers with Mr. Marr on the Shap Granite and the associated Metamorphic Rocks,—to show the nature of the work in which you have been engaged.

Your Sedgwick Essay, on the Volcanic Rocks of Caernarvonshire, is a model of what such work should be. It has already received a well-merited encomium from your present chief, the Director-General of the Geological Survey.

In the past twelve years you have also been a frequent contributor to the pages of the GEOLOGICAL MAGAZINE, in which some twenty articles of yours are to be found.

Lastly, your excellent "Petrology for Students," issued from the Cambridge University Press last year, greatly adds to your credit in this field of research.

This slight recognition from the Council may serve to assure you how highly your past work has been appreciated, and how much more good work we trust that you will live to achieve.

Mr. Harker, in reply, said:—Mr. President,—

I heartily thank the Council for the honour which they have conferred upon me, and yourself for the graceful words with which you have accompanied this award.

In the work to which you have made kind reference, I have confined myself to only one among the several lines of research recognized by this Society. I have, however, always regarded Petrology, not as a study apart, but as a branch of geological science; and whatever value may belong to my results, I owe in large measure to the fortunate circumstances which have enabled me constantly to combine work in the field with work in the laboratory.

Generous appreciation at the hands of those best qualified to judge is an incentive second only to the pleasure of the work itself. To the encouragement which I have at all times derived from the comradeship of fellow-workers, both at Cambridge and elsewhere, is now added that which must always attach to such an honour as the present one; and for the encouragement, no less than for the recognition, I tender my best thanks.

In presenting the Murchison Medal to T. Mellard Reade, Esq., C.E., F.G.S., the President said:—Mr. Mellard Reade,—

The Council of the Geological Society have awarded to you the Murchison Medal, in recognition of your work on "The Origin of Mountain Ranges," containing the records of much original and experimental research. Since you joined this Society in 1872 you have contributed to the various scientific journals, and to this and other kindred institutions, more than a hundred papers on geological subjects, treating of "the Geology and Physics of the post-Glacial Period in Lancashire and Cheshire," "the Buried Valley of the Mersey," "the Drift-beds of the North-west of England," "the Chalk-masses in the Contorted Drift of Cromer," "Tidal Action as a Geological Cause," "the Moon and the Earth," and many other kindred subjects bearing upon Dynamical Geology, to which you have devoted much careful thought and originality of observation extending over more than a quarter of a century, and have never permitted an opportunity to slip of adding to our store of geological knowledge.

This medal will serve to assure you that, although not often present at our meetings, and living at a distance from town, you are neither overlooked nor forgotten by your fellow-geologists here, nor have your labours been unappreciated.

Mr. Mellard Reade replied as follows:—Mr. President,—

It is with mingled feelings, difficult, nay impossible, to express here, that I receive the medal founded by the illustrious author of "Siluria," which the Council of this Society, in the exercise of their functions, have thought fit to award to me. If one circumstance more than another could add to the pleasure which the award affords me, it is, Dr. Woodward, that I receive it through you as President of this Society. I cannot forget that my first little geological venture was launched in the columns of the Geological Magazine, and that ever since you have proved to be a true and consistent friend.

As regards the work and researches of which you have so favourably spoken, it is for others to assess their value, and for me to rejoice that they have been considered worthy of so handsome a recognition. Like the founder of this medal, I began the study of geology in middle life, and doubtless the direction and the character of my researches have been profoundly influenced by previous professional training as well as by natural bias. The study of geology has been to me a labour of love as well as an interesting and healthful recreation. It has also been an education. Doubtless some of the work to which I have directed my attention has been of an arduous nature, but, as Shakespeare says, "The labour we delight in physics pain."

It now only remains for me to thank the Council and yourself for this much appreciated recognition of my small services to geological science, and to assure you that the addition of my name to the distinguished list of Murchison medallists is calculated to inspire and support me in any further work which in God's providence I may be permitted to carry out.

The President then presented the balance of the proceeds of the Murchison Geological Fund to Philip Lake, Esq., M.A., F.G.S., addressing him in the following words:—Mr. Lake,—

The Council of the Geological Society have awarded to you the balance of the proceeds of the Murchison Geological Fund, in recognition of your work in India, too soon interrupted by ill-health. Before you left, however, you had made a solid contribution to the history of the origin of the remarkable Laterites of that region (Mem. Geol. Surv. India, vol. xxiv, art. 3, 1890), as well as to some other Indian geological problems. You have now commenced in Wales: first, in conjunction with Mr. T. T. Groom, at Corwen (Quart. Journ. Geol. Soc. 1893, vol. xlix, p. 426); and at a later date alone, near Llangollen (*ibid.* 1895, vol. li, p. 9), you have given the Society careful and accurate contributions on the geology of these difficult regions.

Nor have you neglected palæontological studies, as your recent paper on *Acidaspis* bears testimony. It is hoped that this award may prove not only useful, but that it may serve as an incentive to continued and important geological work in the near future.

Mr. Lake, in reply, said:—Mr. President,—

I am deeply sensible of the honour which the Council have done me in making this award; for, to a labourer in the cause of science, there is no truer pleasure than the appreciation of his labours by his fellow-workers. It is an additional gratification that it should fall to my lot to receive the award at your hands, since of late I have attempted to follow in your footsteps in the field which you have made so peculiarly your own.

I feel, however, that the award is a recognition far beyond what my work has hitherto deserved; and I look upon it rather as an encouragement to persevere in the researches which I have begun.

In presenting the Lyell Medal to Arthur Smith Woodward, Esq., F.L.S., F.G.S., the President said:—Mr. Arthur Smith Woodward,—

The Council of the Geological Society have awarded you the Lyell Medal, because it appeared to them that the palæontological work to which you have so earnestly devoted your life since you commenced your career in the British Museum in 1882 would have met with the cordial approval of the distinguished geologist and writer who founded this medal.

Trained at the Owens College, Manchester, you had, besides this, an innate love of scientific work, and only needed the opportunity to develop into an accomplished palæontologist of the Vertebrata.

In dealing with the whole field of Fossil Vertebrata, you wavered at first between the varied groups to which your studies invited you; but, after a few papers on Mammalia and Reptilia, you turned with a steady resolve to the study of Fossil Fishes, from which you have scarcely ever departed. More than one hundred papers on Fossil Fishes, besides a descriptive and illustrated Catalogue of Fossil Fishes in the British Museum, of which three volumes have already appeared (1889–95), and two Memoirs on the Fossil Fishes of New South Wales, attest the settled life-line of research to which you now stand committed.

But we have to thank you also for a joint work with Mr. C. Davies Sherborn, F.G.S., of the very greatest usefulness to palæontologists, "A Catalogue of British Fossil Vertebrata," 1890—a most trustworthy and excellent compilation, critically and carefully prepared.

That in the space of fourteen years you should have accomplished so much good work, is due to the fact that you have never wavered from the object which you had set before your mind to accomplish, and even in your numerous journeys in Europe and to North America you have ever kept your ichthyological researches steadily in view.

I trust that this medal, and the good wishes which accompany it from your friends here, will encourage you to the completion of your labours on the Fossil Fishes, and that the remaining group of the Teleosteans may enjoy the same careful and critical attention and study at your hands as you have bestowed upon the other and earlier groups.

Mr. Smith Woodward, in reply, said:—Mr. President,—

I desire to express my thanks to the Council of the Geological Society for the great honour that they have done me in making this award, and to yourself, sir, for the very kind and complimentary terms in which you have presented the medal. During the last thirteen years I have merely tried to make the best use of the opportunities for research afforded by my official connection with the British Museum; and the great gratification experienced in the pursuit of duty of this kind is in itself so ample a reward for the labour involved, that a naturalist thus circumstanced scarcely looks for anything beyond it. When, however, the honourable marks of approbation officially bestowed are unexpectedly coupled with so highly esteemed a distinction as the award of the Lyell Medal by the Geological Society of London, I feel doubly encouraged to persevere and endeavour to merit the compliments that have been expressed.

I was first led to take a special interest in extinct Fishes by attending Dr. Traquair's course of Swiney Lectures on the subject in 1883. I was thus enabled to apply to this field of research the methods that I had previously learned from Prof. Boyd Dawkins when a student in the Owens College. Since that time the kindly encouragement of so many friends—yourself and the late Mr. William Davies among the foremost—has made progress easy; and the very fortunate circumstance that most of the larger private collections of Fossil Fishes in this country have now been acquired by the British Museum, has afforded me favourable opportunities for study such as never have been enjoyed by anyone previously. The biological problems suggested by these fossils seem to me to outweigh in interest the geological questions connected with them to so great a degree, that I have rarely been able to look upon them from any but a morphologist's point of view; and all the more on this account do I appreciate the high honour that is conferred upon me by the Geological Society to-day.

The President then presented one-half of the balance of the proceeds of the Lyell Geological Fund to Dr. William Fraser Hume, Assoc.R.S.M. and R.Coll.Sci., F.G.S., and addressed him as follows:—Dr. Hume,—

Although for several years you have been actively engaged as a Demonstrator in Geology in the Royal College of Science, you have not allowed any opportunities for doing original work in the field to escape you; and your essay on the Chemical and Micro-mineralogical Structure of the several zones of the Upper Cretaceous rocks of the South of England illustrates admirably how such detailed work should best be carried out.

Your papers on the "Black-earth," "the Loess," and on the Chalk of Russia, "on the Genesis of the Chalk," and on "Oceanic Deposits," indicate the bent of your researches towards the microscopic investigation of rocks—a line of study which Dr. H. C. Sorby, F.R.S., a past President of this Society, so profitably engaged in.

The Council hope, by the presentation of this award, not only to mark their appreciation of your past researches, but to encourage you to extend them to other formations with the same useful results.

Dr. Hume replied as follows:—Mr. President,—

At times a feeling of despondency has crossed my mind, when I have considered the vastness of our subject, and the smallness of the contributions which I have endeavoured to add to our knowledge of the past; it is therefore a great encouragement to receive this mark of approval from those whose opinion we most value and esteem. It would, indeed, have been strange if, with the resources of the Royal College of Science at my disposal, I had not availed myself to the utmost of such exceptional opportunities.

Two facts afford me special gratification on the present occasion: the first, that this award should be intimately connected with the great geologist whose historical and geographical methods I have been most anxious to follow to the best of my ability; the second, to receive it from you, seeing that you were the editor who piloted with friendly hand my first publication, at a time when it was especially in your power to damp or re-inspire the ardour of a young enthusiast. Therefore

to you, sir, to the Council, and to the kind friends who have aided me by active counsel or friendly criticism, I hereby tender my most warm and hearty thanks.

The President then handed the other moiety of the balance of the proceeds of the Lyell Geological Fund to Charles W. Andrews, Esq., B.A., B.Sc., F.G.S., of the British Museum (Natural History), and addressed him as follows :—Mr. Andrews,—

Although your scientific career has been but a short one, you have lost no time in engaging in active and earnest studies as a comparative anatomist of the fossil and living Vertebrata, and have already done some excellent work on the remains of the extinct gigantic Birds from Madagascar and from other parts of the world. Your papers on *Keraterpeton* from the Coal-measures, and the Oxfordian genera of Plesiosauria, prove that you have already acquired an accurate knowledge of many points of detail in the anatomy of these extinct reptiles, which can only be appreciated by an equally careful study of existing forms.

In making this award, the Council desire not only to assist and encourage you in the work which you have taken in hand with so much enthusiasm, but they have a confident expectation that you will ere long contribute papers to their Proceedings, which shall do honour to their prescience and bring κῦδος to yourself.

Mr. Andrews, in reply, said :—Mr. President,—

I wish to express my sincere thanks to the Council for the great honour that they have done me, and to you, sir, for the altogether too kind remarks that you have made. It was always my earnest desire to study the structure of animals, but in my wildest dreams I never hoped to have such opportunities as I now enjoy at the Natural History Museum, and I feel continually a sense of responsibility and fear lest I should prove unequal to my task. Having now received this award, I am still further bound in honour to do my utmost to justify it, and to fulfil as far as possible the expectations that you have expressed.

In handing a moiety of the Barlow-Jameson Fund to Dr. G. J. Hinde, F.G.S. (for transmission to Joseph Wright, Esq., F.G.S., of Belfast), the President addressed him as follows :—Dr. Hinde,—

The Council have awarded the sum of twenty pounds from the Barlow-Jameson Fund to Mr. Joseph Wright, in recognition of the valuable services that he has rendered to the palæontology, not only of the Carboniferous rocks in the South, but of the Cretaceous and post-Tertiary deposits in the North of Ireland, and the glacial deposits there, and in Scotland.

Mr. Wright is the author of numerous papers in the Transactions of the Belfast Naturalists' Field Club, on the Irish Liassic and Cretaceous Foraminifera and other Microzoa ; he has also prepared and published many lists of Foraminifera from the Scottish and Irish Boulder-clay and other post-Tertiary deposits.

He has done much good work, extending over many years, when resident in the South of Ireland, in connection with the fossils of the Carboniferous Limestone, and both as regards these, and the newer deposits of the North, his specimens have been always available to anyone engaged in writing on the fossils. To Davidson, Rupert Jones, Holl, Brady, myself, and others Joseph Wright's cabinet was ever accessible and his specimens freely lent for study.

I trust that this award will serve to express to Mr. Wright our appreciation of his services, and will act as an incentive to him to continue his useful geological work.

Dr. Hinde replied as follows :—Mr. President,—

It gives me great satisfaction to receive this award on behalf of my friend Mr. Joseph Wright. He is unfortunately unable to be present, and has sent the following letter for communication to you :—

" I desire to express my sincere thanks for the honour conferred upon me by the Council of our Society in recognition of my past work, and for their assistance in the further prosecution of my researches. Working so remote from the headquarters of the Society causes this award to be the more appreciated.

"I regret that I am prevented from being present to receive it in person, but I hope that the Council will accept this expression of my feelings regarding their approval of my work in a somewhat neglected field.

"For some years past nearly all my spare time has been spent in microscopically examining the Glacial Clays for Foraminifera. My anticipation as to the occurrence of these organisms in clays laid down under Glacial conditions has been fully confirmed both as regards our local deposits and other British clays, and I cannot avoid thinking that this fact must more or less influence our views as to the origin of these drifts."

In handing to A. Strahan, Esq., M.A., F.G.S. (for transmission to Mr. John Storrie, of Cardiff), the second moiety of the award made from the Barlow-Jameson Fund, the President addressed him as follows:—Mr. Strahan,—

The Council have accorded to Mr. Storrie the sum of twenty pounds from the Barlow-Jameson Fund, in recognition of his services for the advancement of geological science while in charge of the Cardiff Museum, and subsequently as a volunteer worker on the geology of South Wales. Mr. Storrie, I am informed, was the first to detect and describe an actual exposure of the base of the Old Red Sandstone near Rumney, and his researches have done much to elucidate the obscure plant-remains from the Silurian rocks of that locality.

In the Rhætic and Triassic strata he found and fixed the exact horizon of certain fossils new to the district, while in the latter he made an interesting discovery of grains of gold. His intimate and accurate knowledge of the Cardiff area proved of great service to geologists at the time when the British Association held its meeting in that town. Indeed, few geologists have worked in the neighbourhood of Cardiff without being indebted to him for assistance.

I have much pleasure in handing you this award for transmission to Mr. Storrie.

Mr. Strahan, in reply, said:—Mr. President,—

It will be a great pleasure to me to forward this award to Mr. Storrie. The pages of our Journal testify to the value of the aid that he has rendered to many Fellows of the Society. I have myself been indebted to him for most valuable assistance in the geological mapping of the neighbourhood of Cardiff. Mr. Storrie writes to me:—

"I regret that it will not be in my power to attend personally to thank the President and Council for the great honour that they have done me. I am afraid that up to now I have not done enough to warrant my selection, but if ever I am able in future to do anything in the way of original work I shall be very anxious to justify this choice and give my whole mind to the accomplishment of the best work possible. You will, I hope, convey in better words than I can the extreme gratitude which I feel for the award."

The President then proceeded to read his Anniversary Address, in which he first gave obituary notices of several Fellows, Foreign Members, and Foreign Correspondents deceased since the last annual meeting, including the Marquis de Saporta (elected Foreign Member in 1889), J. D. Dana (elected Foreign Member in 1851), J. W. Hulke (President from 1882–4), Sir E. H. Bunbury (elected in 1837), the Rt. Hon. T. H. Huxley (elected in 1856), Valentine Ball (elected in 1874), James Carter (elected in 1877), Sven Lovén (elected Foreign Member in 1882), Ludwig Rütimeyer (elected Foreign Member in 1882), W. B. D. Mantell (elected in 1858), Charles Tyler (elected in 1863), E. A. Wünsch (elected in 1875), Hugh Miller (elected in 1874), and Francis E. Brown, late Assistant Clerk to the Geological Society.

The President congratulated the Society on its continued financial prosperity, and on the excellent scientific work carried on under its

auspices. He spoke of the progress of the Geological Survey, and the new development made in maps and memoirs; and congratulated the Palæontographical Society upon attaining its 50th year of existence. He thanked the Fellows for the support that they had given to the GEOLOGICAL MAGAZINE, now in the 32nd year of its existence.

He then resumed the subject of his address of 1895, dealing this year with "The Life-history of the Crustacea in Later Palæozoic and Neozoic Times." He pointed out that the great change between Palæozoic and Neozoic life was observable in the Carboniferous period, when we reached the upward limit of the Trilobita, the Eurypterida, and the Ceratiocaridæ. But before these had disappeared, the air-breathing Scorpions had already come into being as far back as in the Upper Silurian period; the Amphipods and Isopods had also commenced, the former in the Upper Silurian and the latter in the Devonian: this formation also revealed the earliest Macruran decapod, a type still better represented in the succeeding Coal-measures. He showed that there was no sharp division in the Crustacea, but before one order died out and disappeared, other and successive groups had already come into existence, thus illustrating the same gradual evolution marked by so many other groups of organisms. At the same time, he observed that many groups were remarkably persistent, as the Ostracods and some Phyllopods, and the King-crabs (Xiphosura).

Dr. Woodward then traced briefly the development of the orders Amphipoda, Isopoda, Cumaceæ, Stomatopoda, Schizopoda, Macrura, and Brachyura in time, giving a slight sketch of the life-line of each great division and of some of the most noteworthy forms of the several orders. He concluded his address as follows:—

"Last year I invited your attention mainly to the state of our knowledge of the earlier and simpler forms of Crustacea inhabiting the Palæozoic seas, placed in the great division of the Entomostraca. I referred to the extinct Trilobita and the important advance in our knowledge of this group which we owe to American palæontologists. I spoke of the Merostomata, including therein the Eurypterida and Xiphosura—the former aquatic division being now entirely extinct, but having, no doubt, given origin, in its remote ancestry, to the terrestrial and air-breathing Scorpionidæ, which have come down from the Silurian epoch to our time, apparently but little changed in structure; whilst the latter (the living Xiphosura, 'King-crabs') have even adhered, in both their general form and their aquatic mode of respiration and life, to their Palæozoic progenitors. I discussed the Palæozoic 'giant pod-shrimps,' Phyllocarida, placed heretofore with the general group of the Phyllopoda, now claimed as the direct ancestors of the modern Malacostraca, but still represented by one living form, apparently but little changed—the genus *Nebalia*.

"Of the other divisions of the Brachiopoda I said but little, nor could I do justice to the Ostracoda and Copepoda, while as regards the Cirripedia, on which Charles Darwin laboured so long and exhaustively, I have been silent, because I found the whole subject of the Crustacea more than sufficient for two addresses.

"To-day I have attempted, in a very imperfect manner, to bring into the focus of my discourse a summary of the fossil Malacostraca, to which our modern Crustacea chiefly belong. It is true that the evidences of the existence of this division prior to the Mesozoic epoch are but few and scanty; nevertheless, even in Carboniferous times, if not in still earlier ones, we catch a gleam of the light of the living life-forms of to-day, shining clearly, though afar off, down the corridors of time, revealing ancestral forms, the prototypes of those which people so abundantly our modern seas, proving that the living present and the far distant past are indissolubly linked together, and that the stream of life has flowed, from its parent source, through all time, at first in tiny rills and murmuring streamlets, yet ever growing stronger, 'from running brooks to rivers wide,' pressing ever and for ever, onwards from the river to the sea.

"As to the minute details of the course which the evolution of Crustacean life has followed in past times, we can, in many cases, only infer, we cannot absolutely prove our proposition. Thus we have no doubt that the aquatic Eurypterida gave rise to the terrestrial Scorpionida, but we cannot show any direct evidence, because we have *Eurypterus* and *Scorpio* side by side in Upper Silurian rocks, but the earlier evolutionary history is wanting. Again, *Nebalia*-like forms are most probably in the direct line of the ancestry of the modern Malacostraca, and in the Carboniferous period we have *Cumacea*-like forms, which have probably been derived from *Ceratiocaris* and have given rise to higher Malacostraca; but Macruran and other forms of Podophthalmata and Edriophthalmata were already in existence in the Devonian, and both Cumaceæ and Nebaliæ continue to exist unchanged to the present day.

"Looked at broadly, however, the Crustacea show the same upward and onward development which marks other living forms whose geological history can be traced. The great extinct orders of Eurypterida and Trilobita have disappeared; the other Entomostracan orders have survived, but they no longer occupy the whole field; with the close of Palæozoic times the Malacostraca have developed in strength, and now occupy the stage associated with the Tracheata proper, and the King-crabs and Scorpions, which latter, like the Ostracoda and Phyllopoda, are survivals from a pre-Silurian age.

"Truly, 'The old order changeth, yielding place to new.'"

(The address was illustrated by about 100 drawings and specimens of Crustacea.)

The ballot for the Council and Officers was taken, and the following were duly elected for the ensuing year:—*Council*: H. Bauerman, Esq.; W. T. Blanford, LL.D., F.R.S.; Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.; Prof. W. Boyd Dawkins M.A., F.R.S.; H. T. Brown, Esq., F.R.S.; Sir John Evans, K.C.B., LL.D., F.R.S.; Sir A. Geikie, D.Sc., LL.D., F.R.S. L. & E.; Prof. A. H. Green, M.A., F.R.S.; J. W. Gregory, D.Sc.; F. W. Harmer, Esq.; R. S. Herries, Esq., M.A.; Henry Hicks, M.D., F.R.S.; Rev. Edwin Hill, M.A.; T. V. Holmes, Esq.; R. Lydekker, Esq., B.A., F.R.S.; Lieut.-General C. A. McMahon; J. E. Marr, Esq., M.A., F.R.S.; Prof. H. A. Miers, M.A.; E. T. Newton, Esq., F.R.S.; F. Rutley, Esq.; A. Strahan, Esq., M.A.; J. J. H. Teall, Esq., M.A., F.R.S.; H. Woodward, LL.D., F.R.S.

Officers.—*President*: Henry Hicks, M.D., F.R.S. *Vice-Presidents*: Prof. T. G. Bonney, D.Sc., LL.D., F.R.S.; Prof. A. H. Green, M.A., F.R.S.; R. Lydekker, Esq., B.A., F.R.S.; Lieut.-General C. A. McMahon. *Secretaries*: J. E. Marr, Esq., M.A., F.R.S.; J. J. H. Teall, Esq., M.A., F.R.S. *Foreign Secretary*: Sir John Evans, K.C.B., LL.D., F.R.S., F.L.S. *Treasurer*: W. T. Blanford, LL.D., F.R.S.

CORRESPONDENCE.

MR. JUKES-BROWNE AND THE GENITIVE.

Sir,—Mr. Jukes-Browne asks whether I "made a slip in the construction of the name" *Merocrinus Salopiæ*. I answer, "No." I deliberately preferred the name to several alternatives, on the grounds of euphony and brevity. One alternative was "*Merocrinus scrobbesbyrigshirensis*": am I wrong in my preference? Mr. Jukes-Browne intimates that I am wrong; and this forces me to traverse all his assertions.

It is needless to discuss whether *salopiensis* or *salopicus* be the more correct adjectival form of *Salopia*: Mr. Jukes-Browne prefers the latter; the former is the one in universal use. I rejected both, not from considerations of correctness or incorrectness, but because I liked "*Salopiæ*" better. Mr. Jukes-Browne politely but firmly rebukes me. I apologise, indeed, for the unintentional insult to one of his lady friends; but to me, and to all good folk round the Wrekin, "*Salopia*" means primarily Shrewsbury; and, by a well-known figure of speech, we constantly extend the name to embrace the whole "*comitatus salopiensis*." Now Mr. Jukes-Brōwne may dislike genitives as much as did Mistress Quickly, but that does not make them improper. Was it a slip when Tacitus wrote of "*Germaniæ gentes*" (Histor. III, xli), or "*Mœsiæ duces*" (III, liii), or "*plana Umbriæ*" (III, xlii)? If a man likes to talk about the *Merocrinus* of Salop, rather than the Salopian *Merocrinus*, what power in the world is to hinder him?

I fail to understand, I cannot conceive, on what grounds Mr. Jukes-Browne lays down the law. Apart from the usage of classical Latin writers there is nothing to guide one, except the rules and recommendations formulated by various committees of zoologists. In the first code, that of Strickland (which Mr. Jukes-Browne would call the Stricklandian), nothing is said on this point, but genitive forms are accepted as ordinary components of the appellations of species. In the last code, that adopted by the International Congresses of 1889 and 1892, I find these rules:—

"14*b*.—Names of persons to whom the species is dedicated. These names are always to be put in the genitive. This genitive is always to be formed by the addition of a simple *i* to the exact and complete name of the person to whom the dedication is made."

"19.—If the specific name demands the employment of a geographical name, this should either be put in the genitive or employed under its adjectival form, if it was known to the Romans, or if it has been Latinized by mediæval writers. Under its adjectival

form it is always to be written with a small initial letter: e.g. *Antillarum, Galliæ, lybicus, ægyptiacus*, etc."

It is then strange, but true, that the name *Merocrinus Salopiæ* is not only in conformity with Latin usage, but also with the rules of zoologists. As for euphony, tastes differ, especially in different countries. Mr. Jukes-Browne modestly shrinks from the Latinized genitive of "Bell"; some, however, find more pungent offence in the adjectival form of my critic's own name, even when screened by a "jukes" or similar useful prefix. Still, these objections are purely provincial; they would not be felt by a German or Japanese; they have no place in orthography or zoology. And is it not absurd of Mr. Jukes-Browne and myself to be discussing a mode of nomenclature that he has taken a vow never to employ, a vow which I hope we shall both live long to keep?

Natural History Museum, S.W.
March 4th, 1896.

F. A. Bather.

OBITUARY.

CHARLES WACHSMUTH.

Born September 13th, 1829. Died February 7th, 1896.

The Museum of Comparative Zoology at Harvard is about to publish "A Monograph of the Crinoidea Camerata of North America," in two volumes, consisting of 800 pages and 83 plates. This great work is the result of some 40 years' labour on the part of Charles Wachsmuth, of Burlington, Iowa, assisted for about half that period by Frank Springer. Those who have followed the writings of these palæontologists, and who are looking forward to this climax of their efforts, will deeply regret to hear of the death of the senior author, which has deprived him of the congratulations of his colleagues and the joy of an aspiration fulfilled.

Charles Wachsmuth was the only son of Christian Wachsmuth, an eminent lawyer of Hanover, Germany, in which city he was born and educated. He abandoned the profession of the law on account of weak health, and early turned his attention to commerce.

In 1852 Charles Wachsmuth went to New York as an agent for a Hamburg shipping house in the interest of German emigration. Here he remained for two years, but as the climate did not agree with him, he removed to Burlington, Iowa, where he finally settled, having married, in 1856, Miss Bernandina Lorenz. Up to this time Wachsmuth had paid no attention to science, but being still of weak health, he was advised by his physician to spend as much time as possible in the open air, and to take to fossil-collecting. The magnificent remains contained in the Burlington Limestone, especially the fossil crinoids, soon aroused in him the enthusiasm that ceased only with death. In less than three years he had made a collection whose fame extended into other States. Excited by the report of Jules Marcou, in 1864 Louis Agassiz visited Burlington, and struck by the intelligence of Wachsmuth invited him to Cambridge. Thither he went, in 1865, on his way to Europe. This journey was used by

him to good purpose in collecting European fossils, and in studying the crinoids in the principal museums. Finally he visited the British Museum, with one of his magnificent Burlington specimens in either pocket; these were promptly purchased. Fired by what he had seen, Wachsmuth, on his return to Burlington, determined to devote the rest of his life to the study of the crinoids. His want of scientific training was not altogether a disadvantage, since he came to the subject unhampered by the preposterous notions of crinoid, or at least fossil crinoid, morphology that obtained among the older writers. W. H. Niles, a student of Agassiz, had been led to believe, from the published observations of Dr. C. A. White, and from notes given him by Wachsmuth, that a careful study of the distribution of the crinoidal remains at Burlington would be rewarded with interesting results. He came to Burlington and, as he says, "found Mr. Wachsmuth acquainted with many important facts in this connection which could be reached only by a long experience in collecting these fossils, by an intimate acquaintance with the species, and a series of most careful observations." The result of his visit was the joint paper published in the American Journal of Science in 1866, proposing a division of the Burlington Limestone into two horizons, based on the restriction of the various species of Crinoids to one or other of these two. The paper was also of importance as pointing out the gradual progression of crinoidal life and structure from the Lower Burlington to the Keokuk Limestone, an idea afterwards elaborated by Wachsmuth and Springer in their remarkable paper on "Transition Forms in Crinoids," 1878. F. B. Meek, who was preparing the fifth volume of the Illinois Survey, also came to study Wachsmuth's collection, and in that volume are several remarkable notes on the structure and habits of Palæozoic Crinoidea, based upon "some unique and exceedingly interesting specimens" in the collection of Wachsmuth. The authors, Meek and Worthen, remark: "We express our thanks to Mr. Wachsmuth for the zeal, industry, skill, and intelligence he has brought to bear, in collecting and preparing for study, such an unrivalled series of the beautiful fossil Crinoidea of this wonderfully rich locality. Some idea of the extent of his collection . . . . may be formed, when we state that of the single family Actinocrinidæ alone, after making due allowance for probable synonyms, he must have specimens of near 150 species, or perhaps more, and many of them showing the body, arms, and column. It is also due to Mr. Wachsmuth that we should state here that he is not a mere collector only, but that he understands what he collects, and knows just what to collect, as well as how to collect."

Later on Agassiz paid a second visit to Burlington, and for the sum of 6000 dollars induced Wachsmuth to part with his magnificent collection, and also to come to Cambridge to arrange the specimens for exhibition, and to study them and publish the results. After this Wachsmuth made a second collection, by no means so extensive as the first, but still containing many splendid specimens, which he brought with him on his second visit to Europe in 1874, and sold

to the British Museum for £80. The 203 specimens thus obtained, together with 75 specimens received through exchange in 1888, contain many of the finest examples in the Museum, and some which are in their way unique, notably the splendid calyx of *Megistocrinus Evansi*, measuring 8 cm. ($3\frac{3}{16}$ inches) in diameter.

Again Wachsmuth settled down in Burlington, eager to make a fresh collection and continue his studies. He was so fortunate as to fall in with Mr. Frank Springer, then a young lawyer at Burlington, with whose assistance he again gathered together one of the finest collections of crinoids in the world, to receive which he built a special fire-proof museum at the back of his home in Marietta Street. From this time onwards there have appeared a series of important papers, which, with the exception of "Notes on the Internal and External Structure of Palæozoic Crinoids" (American Journal of Science, 1877) have been written by the two friends. Next to the paper just mentioned, which was an epoch-making one in this branch of science, the most valuable is the "Revision of the Palæocrinoidea," published by the Philadelphia Academy. To deal in detail with the differences in our knowledge of these animals that have been due to Wachsmuth and Springer, is impossible on the present occasion, and readers may be referred to the GEOLOGICAL MAGAZINE, Decade III, Vol. VIII, pp. 219–224, for one of the very few accounts of their work that have appeared in this country. We may, however, again point out that these authors were very different from the usual race of species-mongering collectors that flourish too plentifully in similar rich localities. Their aim was not so much to add to the already overladen lists of species as, on the one hand, to sift, summarize, and correct the work of their predecessors, and, on the other hand, to throw what light they could upon the structure and classification of the Crinoidea. It is not the least praise that can be accorded them to say that many of the suggestive views which they have at various times put forward they have at other times overthrown by their own more careful, more extended observations. There are those who jeer at the inconsistencies of science, forgetful of the wise saying that it is only fools who never make mistakes. In searching out his knowledge Wachsmuth was possessed of indefatigable patience; and in maintaining what he held to be the truth, he displayed a vigorous enthusiasm. At the same time he was always ready to discuss objections, and to yield with open mind to more powerful arguments. His generosity to his fellow-workers, and especially to those in England, must not pass unnoticed here. I could speak myself of his kindness, both in correspondence and in person, when I had the pleasure of staying with him and examining his marvellous collection at Burlington; but it is perhaps more fitting that I should quote from Etheridge and Carpenter's preface to their "Catalogue of the Blastoidea in the British Museum," when they say—"Our chief difficulty, the want of adequate material, was soon and simply solved; for Mr. Charles Wachsmuth generously offered to place at our disposal a selected series from his fine collection of American Blastoids. Though it was originally lent

for six months only, the owner's liberality has enabled it to remain in our hands for over five years. Nothing that we can say can express better than this statement the extent of our indebtedness to Mr. Wachsmuth's generosity, which prompted him to expose a valuable collection to a double journey across the Atlantic and a prolonged detention in this country, in the hope of promoting scientific knowledge. Besides providing us with material, Mr. Wachsmuth has also been kind enough to keep us informed from time to time of the progress of his own researches. We tender him our most sincere thanks for the very free use which he has allowed us to make of his unpublished observations." F. A. B.

MISCELLANEOUS.

Palæontographical Society.

THIS Society, which was established in the year 1847 for the purpose of figuring and describing the fossils of the British Isles, issued last year its 49th volume, and the 50th volume may be expected early this year. The monographs in course of publication include those of the Gasteropoda of the Inferior Oolite, by Mr. Hudleston; the Ammonites of the same formation, by Mr. S. S. Buckman; certain Lamellibranchs of the Coal-measures, by Dr. Wheelton Hind; the Devonian Fauna of the South of England, by the Rev. G. F. Whidborne; the Crag Foraminifera, by Prof. T. Rupert Jones; and the Fossil Sponges, by Dr. G. J. Hinde.

Although so much has been accomplished, there yet remains a very large amount of work to be done. Of this future work the more important will be the description and illustration of the Jurassic and Cretaceous Fishes (certain Ganoids excepted); the Jurassic and Cretaceous Lamellibranchs (with the exception of those of the Great Oolite and the *Trigoniæ*); the Gasteropods of the Lias, Middle and Upper Oolites, and Cretaceous Rocks; the Lower Carboniferous, Silurian, and older Mollusca; the Polyzoa of all formations (except the Crag); the Mesozoic Crustacea; the Palæozoic Echinoderms (except the Devonian); and the Insects of all formations.

Unfortunately, Palæontology is not an exact science, and with the multiplication of species nowadays it is difficult to foretell the time when the Palæontographical Society will have terminated its valuable labours.

It has now reached the point of preparing to issue its fiftieth annual volume, and it seems highly desirable that public attention should be drawn to the important work carried on by this Society, in order to attract new members. We can imagine no better way to effect this object than by sending out a circular announcing the *Jubilee* of the Society this year, and inviting all members to celebrate the occasion by a public meeting and dinner, at which all old "pals" should meet once more. The custom was to hold an annual dinner on the anniversary day, and we hope this excellent and time-honoured practice of the Palæontographical Society will now be revived.